SCIENTIFIC RESULTS OF THE SNELLIUS EXPEDITION

IN

THE EASTERN PART OF THE EAST INDIAN ARCHIPELAGO

1929 - 1930

VOL. V PART 3

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN
P. M. VAN RIEL
DIRECTEUR VAN DE FILIAALINRICHTING VAN HET
NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË
AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN
F. PINKE
LUITENANT TER ZEE DER 1e KLASSE

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UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN HET NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP

GEDRUKT DOOR EN TE VERKRIJGEN BIJ
E. J. BRILL — LEIDEN

Snellius Expedition, 1929-1930
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THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
NETHERLANDS METEOROLOGICAL INSTITUTE

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VOLUME V

GEOLOGICAL RESULTS

PART 3

BOTTOM SAMPLES

SECTION I

COLLECTING OF THE SAMPLES AND SOME GENERAL ASPECTS

BY

Dr. Ph. H. KUENEN
(GEOLOGIST OF THE EXPEDITION)

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CHAPTER I

INTRODUCTION

This part of Volume V of the Results of the Snellius-Expedition constitutes the third and last geological investigation to be published in the reports of the expedition. The results in regional geology are being published elsewhere (see bibliography at end of this volume).

Various deep sea expeditions had visited the East Indies before the Snellius-Expedition. Thus the Challenger, Valdivia and Gazelle all passed through the Moluccan archipelago on their world cruises. The Siboga-Expedition under the leadership of M. Weber, however, was devoted solely to the examination of the Moluccan region and among the rich collections brought home, were nearly one hundred bottom samples. In all, the results have been published of the examination of 151 samples from the region under consideration. An excellent summary of the investigations up to 1922 may be found in an article by G. A. F. Molengraaff [1]).

The investigations referred to had brought out the exceptional oceanographical and sedimentary conditions in the eastern part of the East Indies. The deep basins and troughs are filled to the lowest part of their respective rims with almost homogeneous water, corresponding in salinity and temperature to the ocean waters at the depth of these rims. Curiously enough, however, the aqueous contents of these basins made the impression of being a more succesfull solvent of carbonate of lime than the oceanic waters in corresponding depths. Thus the average content of lime in the open oceans is 70% at about 2500 m depth and is still 17% round about 5000 m. In the Moluccan basins the percentage at 2500 m was found to be 25%, and below 4000 m 2%. Various suggestions had been offered to explain this phenomenon, such as convection currents or the addition of CO_2 to the water from submarine volcanoes. Obviously these and other problems could only be brought closer to a solution by the examination of a greater number of samples and of the oceanographical conditions. In this manner it could be hoped to establish more accurately for the separate basins what the connection is between the oceanographical data and the lime content of the samples.

Other problems worthy of special note were the distribution of volcanic materials and the means of scattering on the sea floor, the stratification of the sediments, indications of submarine sliding, the rate of sedimentation, the organic content of the samples, etc.

In order to approach these problems with any chance of succes it was evidently necessary to obtain a large number of samples evenly distributed throughout all the separate basins and troughs. This was rendered possible as a similar need for oceanographical data was felt. By taking a bottom sample at almost every oceanographical station a representative collection was thus obtained. It was not possible to choose either the position or the number of the stations with a view only to the requirements of the geological investigation. The oceanographical desiderata ranked foremost in this respect. But the leader, Mr. van Riel, included in the program of the expedition the taking of bottom samples also at a few spots that seemed of special importance. Had there not been so many calls on the time and attention of the staff of the expedition, a number of additional, interesting samples could have been taken. But as with all investigations of nature in so interesting a region, it is not lack of problems that limits the observations and the collecting, but the necessity of dividing ones attention over so many calls and limitations of time.

For a general description of the expedition and the plan of work into which the soundings had to be fitted, the reader may be referred to Vol. I of the Snellius Reports. The depth determinations were treated by F. Pinke in Vol. II, Part 2, Chapter I. At the end of this volume a list is included of all publications concerning the expedition.

[1]) G. A. F. Molengraaff, „Geologie" in the publication of the Koninkl. Nederl. Aardrk. Genootschap, titled: De zeeën van Nederlandsch Oost-Indië pp. 272—357, 1922.

The author is greatly indebted to various investigators who undertook as specialists the examination of the samples from different points of view. Only by this generous help has it been possible to complete within a reasonable number of years an investigation that would otherwise have taken many times as long and to which the accuracy and comprehensiveness would have stood inversely. Thus to Dr. P. D. Trask [1]) I owe a number of determinations of organic content, to Dr. H. J. Hardon the mechanical analyses and determinations of carbonate of lime, both carried out under his supervision at the Bodemkundig Laboratorium (Soil laboratory) Buitenzorg, Java. Miss C. Koomans made chemical analyses of 6 samples.

The bulk of the investigation, however, was carried out by Miss Neeb who undertook the entire labour of the microscopic investigation of the samples. Most of this volume is occupied by her report and a mere glance at the tables and maps is sufficient to show what an enormous amount of labour was expended by her during the several years she devoted to this task. The present author was indeed lucky to have the coöperation of so able and painstaking a collaborator, who had gathered extensive experience during several years' microscopic work on East Indian soils. He is also glad to acknowledge several helpful criticisms of his own contribution to this volume. Her own report is in the first place a highly accurate treatment of the regional distribution of the various types of deep sea deposits in the Moluccan area. The map summarises the results and the large number of quotations shows the fund of knowledge on the occurrence and the spreading of materials that has been gained. Special mention should further be made of the results concerning the distribution of ash from volcanoes. Of several volcanoes Miss Neeb succeeded in recognising the products in the bottom samples and thus of ascertaining the areas over which they have been distributed. A further step was to obtain data on the rate of sedimentation since well dated major eruptions. On many other topics important observations are recorded and it is pointed out in which direction future investigations should be carried.

In working out these results lack of oceanographical data, especially chemical, was severely felt. The problem of the solution of lime cannot be solved until the composition of the water is ascertained. Also the movements of the water should be at least roughly known. It is hoped that when the oceanographical reports of the expedition become available, more may be said on this and other subjects connected with the bottom samples. It did not seem advisable to postpone the publication of this report indefinitely in the hope of then being able to round off a few theoretical subjects, as it may still be long before all physical and chemical measurements made, have been worked out. Some provisional conclusions are offered.

After the examinations had been carried through, the remaining material of the samples, the slides, mechanically separated matter, etc. were placed in the Rijksmuseum van Geologie, at Leiden. Some material was also deposited at a number of institutes and museums in the Netherlands.

Thanks are due to the other members of the expedition who collaborated in the collecting of the samples, especially to Dr. Hardon and Dr. Hamaker who performed the soundings when the geologist was not on board.

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[1]) Trask published some results in his: Origin and Environment of Source sediments of Petroleum, 1932, pp. 146—147, pp. 259—260; but a large number of additional tests were made at a later date for the present volume.

CHAPTER II

THE COLLECTING AND TREATMENT OF THE BOTTOM SAMPLES

A. INTRODUCTORY REMARKS

In a general way the apparatus for sounding was copied from the German Meteor-Expedition. This expedition having returned shortly before the machinery and implements had to be ordered for the Snellius-Expedition, it was of the utmost value for us to be able to benefit by the experience of an expedition so minutely planned and so carefully carried out. A word of sincere gratitude and tribute to the staff of the Meteor-Expedition is certainly in place here.

It is doubtless owing to this helpful attitude of our German colleagues that we were able to carry out our program as to soundings almost without a hitch and sustaining the loss of only comparatively few instruments.

By way of training a few soundings were taken on the way out from Holland to the East Indies. As they constitute so heterogeneous a collection they are not treated in this report. It should also be noted that at several stations in the Molucca's no wire soundings were taken. Some samples were lost subsequently one way or another, so that a detailed examination was not possible of all the samples originally taken.

B. APPARATUS USED ON BOARD

The soundings were carried out with a *Lucas sounding machine*. Some 350 soundings were taken with this machine for obtaining bottom samples. The wire broke 5 times. The reader is referred to the part of the Snellius report dealing with the vessel and its equipment for a description. (Plate I, and Vol. I of the Snellius reports, p. 53). The soundings with the large sampler were carried out with the *oceanographical winch* with 4 mm twisted steel wire. A description is also given in Vol. I.

The collection of *samplers* consisted of a few Sigsbee samplers, several of the Meteor samplers of 2 and 3 cm width of tube, a large, heavy sampler of 4 m length and some small snappers.

The *Sigsbee samplers* were used for the very deep soundings (over 6000 m) in the Mindanao trough and elsewhere. Here the weight of 9 or 10.000 meters of sounding wire rendered it expedient to drop the weight of the sampler before hauling in. Mr. van Riel had therefore added the Sigsbee samplers to our equipment. They functioned satisfactorily and brought up 23 samples of an average length of $38^1/_2$ cm. This amount is more than that rendered by Pratje's narrow sounding tube. Conceivably this is caused by more favourable conditions at deeper soundings. In any case the two types appear to be about equally satisfactory in respect to the length of sample they procure, but the Sigsbee sample is thicker (see table I, p. 4).

For the sounding off Mindanao of over 10.000 m the apparatus was weighted with two blocks of iron, together 50 kg. The bottom was felt without difficulty. Only 2 out of the 25 times this type was used, did the sample drop out (see Volume I of the Snellius Reports, p. 12).

The Meteor samplers closely resemble the sampler constructed by V. W. Ekman [1]).

They have been described by Pratje [2]) in the Meteor-publication, while Correns [3]) suggested

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[1]) V. W. Ekman: An apparatus for the collection of bottom-samples. Con. Intern. Publ. de circonstance Nr. 27, Kopenhagen, 1905.

[2]) O. Pratje: Bd III, Zweiter Teil: Die Sedimente des Südatlantischen Ozeans. Erste Lieferung 1935.

[3]) C. W. Correns: Bd III, Dritter Teil: Die Sedimente des Äquatorialen Atlantischen Ozeans. Erste Lieferung, A, 1935.

some improvements (see fig. 1 and Plate I; and in Volume I of the Snellius Reports Plate IV and Plate VI and page 92).

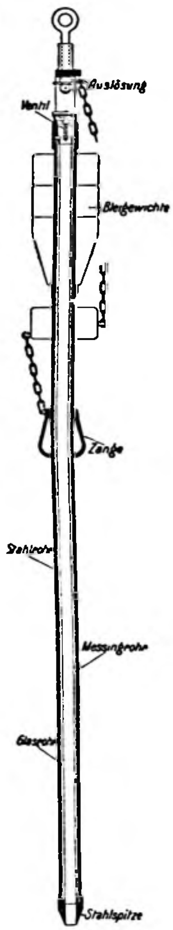

Fig. 1. Section of the sampler of the Ekman-type as used by the Meteor- and Snellius-Expeditions, after Pratje.

On the whole they functioned very satisfactorily. Although the catch of the chain for loosening the jaws had been altered in accordance with experience of the Meteor investigators, it happened several times that the mechanism did not loosen, generally with loss of the sample in consequence. Neither by weighting the rope between sampler and sounding wire, nor by paying out considerable slack after the bottom was reached, nor finally by waiting a few minutes before hauling in, could this hindrance be overcome. A strong spring for forcing down the catch would be useful and care should be taken to round off the flanges that support the last link of the chain.

TABLE I. Average length of samples and frequency of loss.

	Type of sampler	Number of Soundings	Average length in cm	Loss in percentage of soundings
a	Sigsbee.	23	38$^1/_2$	8
b	Pratje 2 cm	38	33	13
c	Schoute 2 cm.	22	42$^1/_2$	8
d	Pratje 2 cm, no inner tube. . .	14	52	
e	Schoute 2 cm, no inner tube	31	55$^1/_2$	
f	Pratje 3 cm	17	41$^1/_2$	13
g	Schoute 3 cm.	5	65	33
h	Pratje 3 cm, no inner tube. .	37	49$^1/_2$	
i	Schoute 3 cm, no inner tube.	3	73	
k	Snellius + glass tubes	1	75	
l	Snellius, no glass tubes . . .	14	155	
m	Snellius	6	148	
n	Pratje at same stations. . . .	6	62	

N.B. Very short samples of less than 5 cm, cases that „hard bottom" was found, or the sample slid out, were all left out of account. Under the heading „loss" are only included cases in which the sample dropped from the sampler before coming on board.

A different type of head piece designed by Dr. Schoute of the Meteorological Institute at de Bilt, was frequently used. The principle was that the valve at the end of the sampler tube was held wide open until the moment of hauling in. This valve had a strong spring that was released at that moment and the sampling tube was thus firmly closed. Theoretically this arrangement is better and the construction worked satisfactorily. The chief aim, of obtaining longer samples, by facilitating the exit of water at the open, upper end as the mud enters at the bottom, appears to have been attained. For if in table I we compare b to c, d to e, f to g, h to i we find in each case that use of Schoute's valve gave samples of greater average length. Not much significance can be attached to k or i as there are few samples, but when combined the result in table II is convincingly in favour of the new arrangement. In fact the increase in length is 24%. An additional advantage is the reliability of the water sample contained above the bottom sample. Not only is the tube washed through more thoroughly during descent, but it is better closed when hauled up.

Out of 135 soundings with Pratje's sampler the jaws failed to close 8 times and out of 77 soundings with the Schoute head piece the jaws were not released also 8 times. In this respect the new head piece is not an improvement. On the other hand the sample appears to have slid from Pratje's

sampler 9 times in 135 soundings, or 7%, but only 2 times in 77 soundings with Schoute's head piece or 3%. In all 212 soundings with tube-samplers of 2 or 3 cm the mechanism failed to procure a sample 27 times or in 12% and the Sigsbee sampler failed in 2 out of 25 or 8%. The Pratje sampler failed in 17 out of 135 soundings, or 13% and the Schoute head piece in 19 out of 77 soundings or also 13%. We may conclude that there is no appreciable difference between the various samplers used by the Snellius-Expedition as far as failure to procure a sample is concerned. The total percentage of failures is 12%, but it should be pointed out, that some cases may have been wrongly attributed to the apparatus and its manipulation, while in reality something else is to blame, for instance a hard object on the bottom. „Hard bottom" was assumed only when the sampler was dented and came up without adhearing traces of mud, but on a small hard object, such as a tree trunk, the sampler might topple over and become smeared with clay, yet without securing a sample. In such a case it is wrong to blame the sampler.

When all data are worked out to averages it becomes apparant that the wider sampler does not only give more material per centimeter of length but also produces longer cores. A fairly large number of samples must be taken, however, before this relation is properly established. By the time the full significance was realised, however, there was some danger of the supply of wider glass tubes, that were also needed for the 4-meter sampler, giving out. This is the reason why the wider sampler was not used more extensively during the Snellius-Expedition. To realise the adventage of the wider sampler the reader should compare in table I, b to f, c to g, d to h and e to i. The average of all samples is given in o table II and works out at 13% longer than that for the 2 cm tube.

TABLE II. Comparison of results with various samplers (from data in table I).

	Type of sampler	Number of soundings	Average length	Improvement
o	b, c, d, e = 2 cm.	105	44	13%
	f, g, h, i = 3 cm.	62	49 1/2	
p	b, d, f, h = Pratje	106	42 1/2	24%
	c, e, g, i = Schoute	61	52 1/2	
q	b, c, f, g = with inner tube . .	82	39	36%
	d, e, h, i = no inner tube . . .	85	53	

A number of slight alterations were tried during the expedition to obtain longer samples. Although one can find occasional reference in expedition reports to the fact that the sampler penetrates deeper into the mud, than the mud enters into the sampler, it had up to the time of the expedition never been sufficiently stressed, to my mind, that this is the chief difficulty encountered, when trying for long cores [1]).

The mud on the sea floor is generally so soft that a sampler of 30 kg, dropped at a speed of 2—3 meters per second, will frequently drive its way in right up to the hilt, in our case the weights. It is discouraging on opening a sampler streaked with mud as far as the weights (± 1.25 m) to find the sample is only half that length or even much less.

The various ways in which it was attempted to increase the length of the samples may be mentioned. A greatest possible speed at the moment the bottom is attained, that is 2—3 meters per second; a small speed to allow the mud to enter the sampler and the water to flow out at the upper end; a flattened end to increase the pressure on the mud and thus force it into the sampler; careful centering of the glass tubes; placing a sharp, obliquely cut off mouth piece of thin sheet iron at the end of the tube. None of these arrangements had any appreciable influence on the length of the samples. The one may be more advantageous under certain conditions than the other, but as one seldom knows in advance whether to expect a hard or a soft, a crumbly or a tough consistency of the sediment one can neither make systematic experiments, nor choose the best mouth piece before sounding.

[1]) Pratje (l.c. p. 25) later showed the samples to be on the average half as long as the minimum depth to which the sampler penetrated.

Finally, however, an arrangement was struck upon that proved satisfactory. Pratje states, that the reduction of the friction between mud and the inner side of the sampler, by using a glass tube within the steel one must increase the length of the sample. The large sampler, to be described presently, was therefore also fitted with an inner lining of glass. When it was found that a sample obtained with this instrument fell far short of expectations and that the inner tubing was more of a hindrance than of an aid, this glass lining was left out in the next sounding and the steel head bored out to the inner width of the remaining steel tube. The result was excellent, for the samples obtained were henceforward nearly three times those of the small sampler.

This success with the larger sampler caused Dr. Hardon, to suggest a similar operation on the normal samplers. The result was astonishing, for the average length of the samples was increased by 36% (see table I). From this result it follows that the internal diameter of the sampler is not the most important factor or the smoothness of the inner wall but the thinness of the wall. For three different sizes the removal of the inner tubing (the narrow and the wide Pratje sampler and the large Snellius sampler) in each case resulted in a very appreciable lengthening of the sample (Table I and II).

The question may also be considered, whether enlarging of the opening at the upper end to allow the water to flow out more freely would have an advantageous influence. This supposition might be founded on the remark made by Piggot [1]) in describing his wonderful sampler that is shot into the mud by a charge of gunpowder on arriving at the bottom. On page 680 he tells us, that no samples were obtained until a satisfactory device had been perfected — the so called water-exit port — for allowing the easy escape of the water out of the tube, while the sample enters at the bottom. In our case, where the sampler enters the mud so much more slowly, the importance of this part of the mechanism must be smaller. In fact it can be directly shown to be of hardly any influence. When, namely, the inner tubings are taken out, the sample entering at the bottom is much more voluminous than before. Consequently a greater amount of water has to escape at the top. Yet the samples were longer. The success of Schoute's valve, however, shows that the change would have been greater still, if the exit at the top had been enlarged correspondingly. It is therefore by no means proposed to neglect this feature in future designs. The chief character to be aimed at is a sampler with as thin a wall as is compatible with inflexibility of the whole, next in order comes a wide and if possible streamlined exit and in the third place a considerable width. The larger the internal diameter, provided there is sufficient weight and speed to force the apparatus into the bottom and the smoother the inner wall, the longer the sample would be.

Besides the advantages already mentioned, a greater internal diameter has the additional merit of securing thicker cores, therefore with more material for examination per cm of length as Correns already pointed out (l.c., p. 10).

The average length of all samples taken by the Meteor in the Southern Atlantic by Pratje is 44 cm. (Pratje l.c. p. 24, 25). He shows that the length varies with the nature of the deposit. No comparison can therefore be made between his and our results, but as we of the Snellius used the same apparatus up till the time the alterations were made, it may be supposed that the slightly smaller length obtained up to that moment was caused by a different composition of the samples. I do not doubt that the Meteor would also have increased its average by alterations in the apparatus such as we made.

When the sampler without a glass tube has been brought on board with a core inside, the latter has to be taken out, examined and stowed away. This was done by pushing a glass tube into the sample from the bottom right to the top. Care must be taken that the tube does not slide in obliquely and run up against the inner wall of the steel tube, for it is then apt to break and spoil the sample. For the same reason the outer diameter of the glass tube should be slightly less than the inner diameter of the sampler. As the thickness of the glass is added to the contents of the sampler when the tube is pressed in, the sample bulges out inside the glass tube. The sample in the tube thus becomes some 20% longer than the original. Apart from the advantage of representing more material, there is the disadvantage of distortion and inaccurate data concerning the thickness of layers. The distortion proved to be but slight, as sharply layered cores were obtained by this method. The lengthening can be taken into account when stating thicknesses.

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[1]) Ch. S. Piggot: Apparatus to secure core samples from the ocean-bottom. Bull. Geol. Soc. Am. Vol. 47, pp. 675—684, 1936.

It has not yet been ascertained beyond doubt whether the shorter length of the core as compared to the depth of penetration of the sampler is due to: 1. a gradual loss, rendering all layers, or only the deeper ones, in reduced condition; or 2. giving the upper strata correctly and missing the lower ones; or finally. 3 giving a series of pieces that were originally some way apart. Until we know what is the original thickness of a mud layer, of which we have obtained a core in our sampler, it is not necessary to worry about a lengthening of a few percent that can moreover be measured.

The precarious and troublesome business of getting the sample into the glass tube could be done away with by following a suggestion made by Tarasow [1]) to use an inner lining to the sampler of celluloid. The author does not feel sure containers of this material would be satisfactory and hold out till the sample is examined. But if this was found to be the case it seems an ideal solution of the problem. That the sample may be studied as to colour, stratification, and even biological contents without opening the tube and in the original wet condition is an advantage that one would not easily give up. Otherwise the copper lining, used by Piggot presents various advantages.

Pratje showed at a later date (l.c. p. 26) that a mouth piece that is slightly narrower at the tip, than the inner diameter of the sampling tube was advantageous to the length of the samples when taken by hand in shallow water. Although it seems probable, it is not quite certain, that this would be the same for most or all deep sea soundings. A future expedition would therefore be well advised to take different types of mouth pieces and to start with a few soundings for comparisons in various types of sediment.

Correns (l.c. p. 2) is of opinion, that sometimes the sample does not break off as soon as the sampler starts to be withdrawn out of the mud in which it is planted. In this manner the discrepancy between length of sample and depth of penetration might also be partly explained. Personally I believe the valve at the upper end always functioned perfectly and the sample did not slide back at all during the extraction of the sampler from the mud. This opinion is based on the fact that when a sample drops from the tube or is pushed some way out, there is practically always a film of dirt left on the inner surface of the glass tube exactly showing to where the sample originally reached. No such ,,high sample marks'' were ever observed in the tubes when they were taken out of the sampler on board the Snellius. This seems to show that the cavity left in the sea bottom during withdrawal of the sampler, is directly and progressively filled by water finding its way along the outside of the sampler. That this is the manner in which water runs in to allow the sampler to be withdrawn is further shown by the following observation. The lower end of the sampler is slightly wider than the remainder of the tube, a rest having to be provided for catching the closing-jaws that drop along the outside. When a tube was being used on board the Snellius in which the steel mouth piece, — and therefore the wider rest — were absent, it was found that instead of needing 20 to 30 kg extra stress to pull the sampler out of the mud, no less than 80 kg was required. After a few succesful attempts this sampler was lost by rupture of the sounding wire. It follows that the greater or lesser ease with wich the water can find its way along the outside of the tube to the lower end of the ,,planted'' sampler, determines the amount of suction to be overcome; in other words the valve at the top closed hermetically and the sample must have broken off immediately. Piggot's sampler has an ingenious arrangement for facilitating the flow of water to the lower end of the tube during extraction from the mud. A few grooves run the entire length on the inner surface of his steel tube thus leaving a canal between it and the copper lining.

The Monaco-snapper, similar to the type used by the Meteor, did not at first function satisfactorily, coming up either open or empty. After the jaws had been weighted there was some improvement. We afterwards added a weight placed around the rod. Then the snapper not only functioned almost perfectly, but it also sank swifter, thus saving considerable time on deeper soundings. In soft sediments and sand it was frequently more than half full, and on pebbles it seldom came up without securing a fair sample (see Plate I).

With the weighted Monaco-snapper 97 soundings were made with 17 failures. How many of these failures were due to a bottom swept clean of debris is not known, but several cases were certainly due to the apparatus and its handling.

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[1]) N. J. Tarasow: Celluloid Tubes for Sampling Cores of Deep Sea Mud. Nature, 1935, p. 263.

The large sampler of the Snellius-Expedition has been described some years ago [1]). It was primarily constructed with a view to taking long samples in the Kaoe baai in Halmahera, in the hope of reaching glacial fresh-water deposits in this basin. It was therefore only used a few times before that locality was visited towards the end of the expedition, but more frequently afterwards. If it had been known beforehand, that the instrument worked so succesfully, some arrangement might have been provided for facilitating its operation. It could then have been employed much more frequently, as will be shown presently.

It was built on the same principles as the Ekman sampler but its length was 4 meters and its maximum weight 160 kg. It had to be payed out on the 4 mm twisted steel wire of the winch for oceanographical serial measurements. When after its first trial the sample was found to be only slightly longer than that obtained with the small instrument, the inner tubing of glass was discarded and the mouth-piece was bored out to the same size as the tube.

The tube consisted of steel and had an inner diameter of 45 mm and an outer diameter of 60 mm. The widest part of the mouth-piece, to catch the jaws, was 75 mm and was therefore 15 mm wider than the actual sampler tube. This arrangement proved to be of prime importance. As was already pointed out above, the small sampler was much more difficult to draw out of the sucking mud, when not provided with this wider mouth-piece. The extra force, besides the weight of the small sampler and payed out wire, required to pull up the sampler, was 80 kg in stead of 20 to 30 kg. Even with the wide mouth-piece the large sampler generally needed an extra pull of 200 kg on the wire to extract it from the mud. Without this arrangement it is likely that the wire would not have stood the extra strain in extreme cases. Thus the wider mouth-piece allows one to use a sampler of double the weight that could otherwise be used, with the same maximum strain on the wire. Doubling the weight ensures a much deeper penetration of the sampler, than would the removal of the wider mouth-piece.

At the upper end the sampler could be weighted up to 160 kg. The maximum pull on the wire, when a sounding was taken in 5000 m depth, was 600—700 kg. The wire had a theoretical breaking strength of 1500 kg. After more than a year's use it was found to be able to stand half that amount without any signs of danger. In smaller depths the sampler might quite safely have been made 250 kg.

The upper end of the sampler tube was closed with a valve similar to that of the Meteor sampler. This part is of prime importance as it precludes the loss of part or all of the sample, while the tube is being extracted from the mud, or is dangling above water before coming on board. There were also spoon-shaped jaws that slid along the outside of the tube and closed it at the lower end when being hauled up. This arrangement, together with the mechanism for releasing, is the most complicated and expensive part of the apparatus. As far as our experience went it could have been missed quite well. Deeper down in the sediment the consistency is firmer and the great weight of the sampler made it penetrate far enough to catch this harder part in the tube. When brought on board it was always found to be sealed with compact sediment, that was hard enough to render the extraction difficult.

Between the wire and the sampler were ten meters of double sounding line. Hoisting this line and then bringing the sampler on deck was a task for which many hands were required and this in turn greatly reduced the number of times the sampler could be used. (See Plate I and Volume I of the Snellius reports, Plate IV, Plate V, fig. 5 and Plate XXVIII).

The sampler was dropped at a rate of about 3 meters per second, about the maximum speed that can be attained without fear of loops twisting into the wire. Our deepest sounding with this instrument was just over 5000 m with a not very rough sea (force of wind 5). Under these conditions the bottom was sounded without the slightest difficulty or doubt.

The extraction of the sample from the tube was a troublesome and difficult task. In order to keep the sample in good condition and to be able to study the stratification, colour etc., it was absolutely necessary to get it safely into glass tubes. The following procedure seemed to be best.

The sampler was laid on deck and the water on top allowed to trickle away. With an iron rod, a wad of cotton and a wooden stopper were pressed against the upper end of the sample, the length being measured at the same time. The free end of the rod was then placed against some resisting

[1]) Ph. H. Kuenen: Die Viermeter Lotröhre der „Snellius"-expedition". Ann. d. Hydr. u. Mar. Met. 1932, pp. 93—97.

object. Then a glass tube of 3 cm inner diameter and 150 cm long, was pressed into the lower end of the sample. The sample, as described above for the small samplers, was extended somewhat by this procedure owing to the thickness of glass tube. Friction prohibited the extrusion of the mud between the mouthpiece of the sampler and the glass tube. While the glass tube is thus slowly sunk into the lower end of the sediment, it may be observed that the sample gradually bulges out beyond the end of the sampler inside the glass tube.

When the glass tube has thus been forced in as far as it will go without fear of breaking, the contents of the sampler (sediment plus tube) have to be stamped out a bit with the iron rod. The portion of the sample outside the tube can be removed and dried; the tube can now be pressed in again as the friction has diminished. A few of these operations and the tube is full. One meter of the original sample is extended to 120 or 130 cm by this treatment. The tube is finally removed and a new one inserted. When measuring the tickness of strata the lengthening of the sample must of course be taken into account.

Great care must be taken to insert the glass tubes centrally, for as soon as they run up against the inner wall of the sampler they break and a part of the sample is lost.

C. SUGGESTIONS FOR A NEW SAMPLER OF THE SNELLIUSTYPE

On the experience gained during the Snellius-Expedition and on results obtained by others, some suggestions can be made for the construction of an apparatus for future work. Assuming that a winch is present with a strong wire for the oceanographical work, in my opinion the Snellius sampler with a few improvements may be preferable to Piggot's gun-sampler. The mechanism is much simpler and cheaper and it presents no danger to the operators. In consequence of the great weight the bottom is sounded without any difficulty, provided the sea is not too rough. This is another advantage over Piggot's gun-sounder. This implement does not appear to indicate automatically when the bottom is attained in greater depths. One is forced to pay out more than the anticipated depth. The possibility of the wire coiling into loops and breaking when hoisted is a well known danger in sounding operations, that should be avoided on account both of the loss of time and of instruments. The Snellius sampler has the further advantage that the sounding can be combined with a serial measurement of temperature and water sampling. At a deep oceanographical station a couple of hours can be saved if a normal wire sounding can be left out. It need hardly be stressed how important the saving of time may be. Thus the Meteor-Expedition would have saved at least a day for other work on each of its crossings of the Atlantic; the Snellius-Expedition would have been able to spend an extra fortnight on anchoring stations, echo-soundings, or some 30 more oceanographical stations, if the large type had been systematically used from the very beginning. If the vessel is not provided with a powerfull winch and does not intend to sample the water, a comparison would have to be made of the costs of such a machine as compared with Piggot's sampler and of their working costs, and the merits of the two systems should be carefully weighed against each other. Though probably more expensive than a few Piggot samplers, the winch has the advantage of being useful for other purposes also. As far as the writer is aware Piggot has secured a sample of 8 feet 8 inches as maximum achievement. This is about 2 feet more than the longest Snellius sample (206 cm). The two systems appear to render samples of the same order of length with a slight balance in favour of Piggot's sampler. The Snellius sampler is certainly open to improvements, however. Possibly we could construct an even larger Piggot sampler and use it on a strong winch, combined with an oceanographical series. The instrument might be too unwealdy for constant use, but only a few cores of several meters length would be invaluable to geological science.

In the opinion of the writer the following alterations of the Snellius sampler would be worth trying. To lengthen the tube to 6 meters, increasing the internal diameter to at least 7.5 cm and adding to the equipment one with a diameter of 10 cm. The wall need not be more than a few mm thick. To place a celluloid tube inside for directly receiving the sample, so as to do away with the transference from sampler to glass tubes. An experiment should first be made to ascertain if celluloid containing a salt-water sample will keep for a long time. They can of course be sealed hermetically with celluloid glue. If they are not satisfactory we might either use Piggot's copper lining, or the Snellius method with glass tubes. In the latter case an arrangement should be made beforehand for

guiding the tubes, while being inserted into the sample. To cut some narrow grooves in the inner face of the tube to help withdrawing the sampler in the manner followed by Piggot. To use a slightly narrowed mouth-piece as suggested by Pratje. To enlarge the opening at the top for a free exit of the water, but retaining a strong valve for closing after the sample has entered the tube. The spoon-shaped jaws for closing the lower end need only be provided where a sandy bottom is expected. The weights should be at least 250 kg if the winch and wire are strong enough. A dynamometer on the wire is necessary and if the sampler does not come up directly, it should be drifted out in the normal manner for sounding tubes [1]).

An arrangement should also be provided to facilitate the hoisting and bringing the sampler on board quickly and with few persons. In any case it would be advisable to have the weights fastened so as to be removable one by one, while the sampler is still hanging over board. The author feels confident that a sampler constructed and operated on the lines here indicated will give satisfaction, both by saving valuable time and taking large and long bottom samples. It does not seem unlikely that an average length of 2 m or more could be attained, as our 14 samples already show an average of 155 cm (see table I, p. 4). The advantages from the geologist's point of view of the Snellius sampler are, that pro centimeter of length the sample has a large bulk, thus facilitating investigations, that the samples are about 3 times as long as those of a small sampler and finally that much firmer sediments are secured. Thus one generally only procures short samples in the neighbourhood of volcanoes with a normal sampler. A large and heavy instrument passes right through the layers of volcanic strata, each derived from an eruption of the volcano or by the sliding of coarse material down the slope.

D. THE SOUNDINGS

The geologist of the „Meteor", Pratje has given valuable advice in his report as to the procedure when sounding. Our own method was essentially the same. The only important difference being, that we paid out a few meters of wire after reaching the bottom and waited one or two minutes before hauling in again. This was done with a view to loosening the jaws of the sampler. When the snapper is used, however, one should haul in immediately to avoid toppling over of the instrument.

METHOD OF SOUNDING

The following short description of the sounding manoeuvre may prove of use to later expeditions.

The sampler is first prepared and then payed out by two men on ten or twenty meters of rope, a third seaman standing on the sounding platform letting out the last few meters. Then the water sampler is attached to a short piece of thick wire above the rope. The sounding wire is then allowed to run out 1 meter so that when next the spar for keeping the wire clear of the ship is let out, the end of the wire is not pulled over the pully at the end of the spar. Then the brake on the reel of the sounding machine is slowly lifted until the pull of the running out wire is about 10 kg and the taut wire can be bent with a finger. The speed is then some 3 m per second for the Pratje sampler and some 2 m for the weighted Monaco sampler. When 150 m have been payed out this balance is about attained.

Some 500 m before touching bottom a dynamometer is attached to the wire and with the brake the pull is regulated at 20 kg, giving a speed of 2—2$^1/_2$ m per second for the tube sampler and 1—1$^1/_2$ m for the grab sampler. At touching the bottom the reel will generally first stop and then start to unwind slowly by the weight of the wire. At the moment of touching an echo-sounding is also taken and the wire is allowed to run out another couple of meters. The Monaco sampler must be hauled in immediately to avoid its topling over, the tube on the other hand is left planted in the mud while the thermometer adapts itself to the temperature. The wire is then gradually hauled in and the pull watched on the dynamometer. At the moment the sampler loosens out of the mud the depth and the pull are noted and also the angle of the wire with the vertical. From these data the wire-depth is found.

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[1]) If a deap sea anchoring outfit is available a still larger instrument could be used.

After winding in 100 m the dynamometer is taken away so as to avoid unnecessary wear. The pull on the wire is 80 kg when 5000 m is still out, 70 kg at 3000 m, 65 kg at 1000 m and less than 60 kg for the last 500 m. With 150 m out one must slow down so as to haul in the last few meters carefully. Some difference will be found in the reading of the measuring wheel in consequence of slip during the paying out. As the minimum pull during the downward journey should not sink below 5 kg, the average should be increased with rough weather and consequently it will take longer to reach the bottom.

The Lucas sounding machine is described on p. 53—57 of Volume I of the Snellius Reports.

As a detailed treatment of the depth determinations by wire soundings is to be found in Vol. II, Part 2, Chapter I, by F. Pinke, and some remarks may also be found in Volume V, Part 1, by the writer, this aspect of wire soundings can be passed over here.

I include a design for a sounding register, slightly altered from the one I used on the ground of experience gained during the expedition. It should be printed on strong paper, that can stand being wetted and should have a broad margin at the top for binding in book-form or securing in ring-leaf books or some other system of binding.

E. TREATMENT OF THE SAMPLES

In the section dealing with the apparatus the method was described by which the samples were introduced into glass tubes. If the sampler had been used with the tubing inside, the latter could be extracted, when the contents of the mouth-piece had been pushed in after the rest. The sample was then allowed to slide a little further or it was pushed if necessary, then the tube was cut off a little way beyond the sample.

After this, melted paraffin was poured on to both ends. It is best not to use paraffin with too high a melting point as it shrinks on consolidating and does not seal the sample. The ends of the tube were then corked with rubber stoppers, the number of the station and sounding scratched in with a diamond, a paper label added for convenience. Finally a brolon capsule was pushed over the ends and allowed to dry. Cellulose glue might also be used. The sample was then ready for packing. First, however, the colour, stratification and other properties were noted.

This method of keeping the samples proved satisfactory. Although some samples blackened after a few months, by the activity of anaerobic bacteria, most of them remained in good condition for years. Correns suggests formalin as a disinfectant, and sublimate could also be used. For samples to be analysed on organic matter a disinfectant is important. Possibly sealing wax is even better than paraffin, as Correns suggests (l.c. p. 5) because the latter material does not seal off hermetically. As there was only a small chamber of air at both ends of our tubes, the paraffin was less apt to work loose with our samples, than with the halved samples of the „Meteor". The sediment clinging to the jaws, or from outside the glass tube, was also collected, dried and packed in tins. A small amount was washed and mounted on a slide for preliminary investigation and a rough estimate of the percentage of $CaCO_3$ was made.

When a number of tubes with samples had thus been brought together they were packed and sent off to Holland. It was not realised at the time that this packing should be done so carefully as to seem quite exaggerated. During the general hurry and confusion of busy packing the last few days of the expedition one box containing samples, that were only provisionally stowed, was nailed up by my native help and placed with the other boxes ready for expedition. Although the glass tubes were all tightly held between wooden supports at three places along their length, they had not been rolled in paper first, and no packing material was stuffed in between. On the way home one of the tubes must have got broken and the rolling of the ship and the repeated transshipments must have caused the loose pieces to smash all the other tubes. When the box was opened, a heap of mud and glass splinters, hopelessly jumbled together, was all that remained. The author hopes that mention of this mishap, for which there can never be sufficient excuse, may caution others and save them a like humiliating experience.

Another mishap, that may overtake one, is a wrong numbering of the tubes. Especially when the soundings have to be carried out in quick succession, as was frequently the case during the Snellius-Expedition, one is apt to get muddled between the samples. Thus I was once forced to admit not

Sounding no. 71 Station no. 83	Region: *South of Java*	Date 1.10.1929

Instrument
snapper
sounding tube: *Schouten sampler 2 cm, without inner tube*

weight	*25 kg*
rope	*10 m*
other instruments	*water sampler* B_{11}

Observer	*X*
Wind	5
Waves	3

Time

beginning of sounding	7^h15
beginning of hauling in	8^h05
end of sounding	9^h20
remarks	*waited 5 min. before hauling in*

Depth

count at beginning	10
count at bottom	5270
count at finish	—25
sounded depth	5305
echo depth	5330

Speed, etc,

paying out speed	2—3 *m/sec*
hauling in speed	2 *m/sec*
angle of wire	5°
maximum strain	92 *kg*

Results

length	52 *cm*
weight	
penetration	75 *cm*
hard bottom	

Treatment and Stowage
Glass tube, remains dried in tin

Shipment: *in box Sn* 10 *Ambon to Leyden,* 7.12.'29

Description of sample

colour	*light buff*
upper end	2 ½ *cm dark brown*
consistency	*plastic, hard*
grain size	*medium + clay*
organic remains	*Foramini fera, Diatomea, some Pteropoda*
inorganic particles	*a few grains of pumice*
$CaCO_3$	*large amount*

Remarks
joint in sounding wire at 3300 m renewed

Use of sample

upper 2 cm	:	*$CaCO_3$ determination*
2—12 *cm*	:	*grain analyses + microscopic examination*
12—20 *cm*	:	*organic content determination*
42—42 *cm*	:	*sent to Dr. Z. for radioactive determination*

Field determination
Globigerina ooze

knowing what was the right side up of an important part of a sample. In another case a mistake was made in the numbering and as this was not discovered till long after at home, the true state could not be reconstructed. Finally a couple of mistakes with numbering appear to have been made with samples that were sent over to Java for the mechanical and chemical analyses. It can not be ascertained at which end of the voyage the mistakes were made. It was thought better to discard all doubtfull samples, rather than to incur the possibility of using wrongly numbered samples. In this respect also we can only emphasize the necessity of the utmost vigilance and care.

The amount of material required by Dr. Hardon for the mechanical analyses and determinations of calcium carbonate was relatively large, about 20 grammes. So as not to spoil the samples more than necessary in providing this amount a core was bored out of the sample with a brass tube, 1 cm in diameter, and the cavity afterwards filled with paraffin. By this method it was possible in most cases to extract a core of some 30 cm length, while leaving the visible part of the sample intact. A disadvantage is that in stratified samples the various strata are not sampled separately. For these cases one might do better to extract the sample and cut it lengthwise, using half for analyses and keeping the remainder intact as far as possible. With very soft samples the coring method failed and the mud had to be scooped out. Of some very short samples the entire available amount had to be sacrificed for the analyses.

Should the samples be analysed on board? This question is of importance as the staff of the Meteor-Expedition spent a lot of time and much of their valuable material on investigations carried out during the voyage. In the case of the Snellius-Expedition a similar plan was ruled out by the call made on the geologist's time for other work, such as photography and filming, examination of the echo-sounding results, etc., but above all for frequent visits to the shore. Not only were many days spent on the various islands visited, but the results of the fieldwork had to be worked out in more detail than usual. As so many disconnected surveys were undertaken and the final working out would not be possible till after many years, it was expedient to make as detailed notes as possible immediately after return on board.

Now that the results of the Meteor-Expedition are becoming available it is increasingly obvious, that the drawbacks to laboratory work on board are so great, that the time spent on the preliminary examination of the bottom samples was mere waste, costing moreover a lot of precious material. No data appear to have been ascertained that influenced the subsequent geological work, that could not have been gained by merely examining the remains on the jaws of the sampler. On the other hand the samples keep much better in their original glass tube until the actual laboratory work at home begins. If the plan of an oceanographical expedition is such as to give the geologist plenty of time, it would be more advantageous to spend it on helping with the chemical or biological work or echo-sounding, than in using up valuable samples in laborious examinations that have to be done all over again at home.

CHAPTER III

REMARKS ON SOME CHEMICAL PROPERTIES OF THE SAMPLES

A. ORGANIC MATTER

1. Organic content of the bottom samples

A number of samples were analysed on nitrogen by Trask and his results may be found in his well known book. Subsequently Trask and Hammar made a larger series of determinations both of nitrogen and carbon that are published in this volume for the first time. Several duplicate tests have been averaged in the table.

Dr. Trask added the following remarks. The figures are given in percentage of ovendried weight

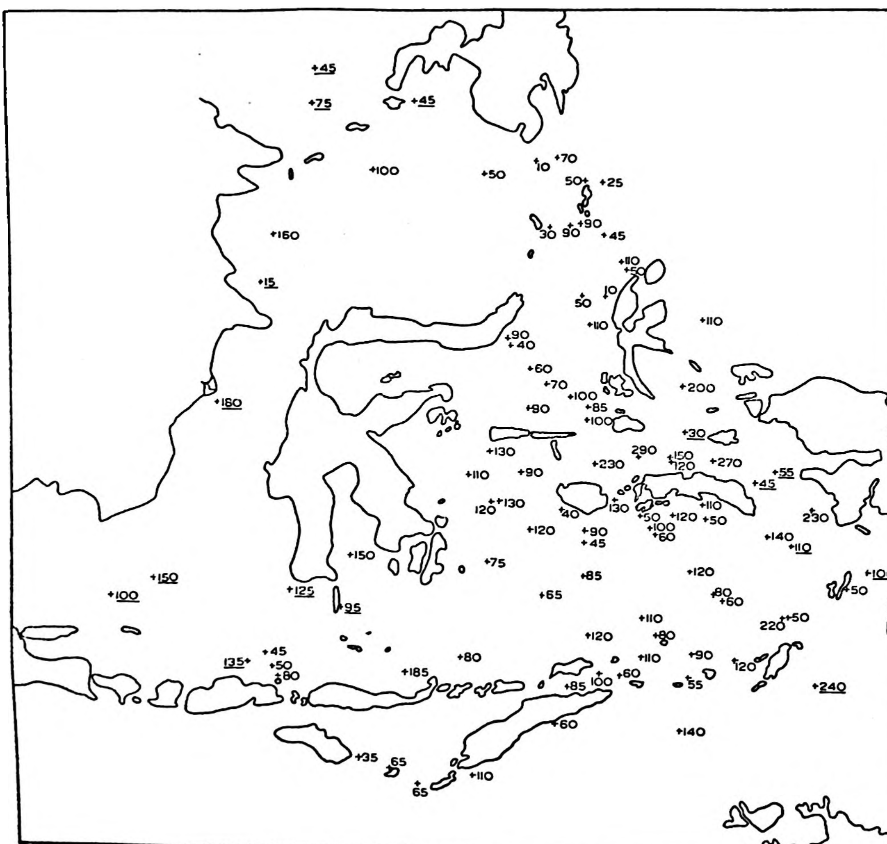

Fig. 2. Map showing the organic content of the analysed samples. The numbers give the thousandth part of a percent of nitrogen. The underlined numbers are the older determinations from which 1/3 has been subtracted. Scale 1 : 16.000.000.

[1]) Trask, P. D.: Origin and Environment of Source Sediments of Petroleum, 1932.

of the entire sediment. The probable error of the individual nitrogen determinations is estimated to be 0.005 percent and for the carbon 0.05 percent. The carbon was determined by oxidation with chromic acid. With the concentrations of reagents used, a factor of 0.6 has been used in the computation of the results given in the analyses. This is the figure S. A. Waksman used for recent sediments. The factor 0.5 is much better for ancient sediments. Trask found the ratio of carbon to nitrogen in recent sediments to be about 8.5. In our samples the average nitrogen is 0.100, the average carbon 1.23. The ratio of carbon to nitrogen is therefore 12.3. If a factor of 0.5 instead of 0.6 were used, the ratio would be 20 percent less, that is roughly 10.

Since these determinations were made Trask has continued his investigations. He now calls the carbon determinations „the reducing power" of the sediments, and uses the factor 0.5. For more details the reader is referred to some papers by Trask [1]). A few general comments may be offered on the results of the analyses. The high carbon ratio is partly due to a few exceptional sediments. The three samples from the Kaoe bay with a ratio of about 20 are abnormal. The deeper water of this bay is stagnant and contains H_2S, the only example encountered in the East-Indies. As anaerobic conditions have developed in the water (see fig. 6) it is not surprising that the C/N ratio is out of the ordinary. Moreover, the ratio increases in all samples towards the lower end. Much of the analysed material was a mixture from the whole length of the sample. The ratio must consequently tend to be slightly higher than if only short cores or snapper samples had been used. The average of the whole region, apart from the Kaoe bay and using only the upper ends of those samples of which both ends

TABLE III.

Station	length	carbon-nitrogen ratio	
		upper end	lower end
167	29 cm	13.2	13.3
189	168 cm	11.3	13.5
203	44 cm	10.2	12.6
330	152 cm	10.0	11.5
331	187 cm	11.3	16.1

were analysed separately, is: nitrogen 0.096, carbon 1.12, ratio 11.7. There still remains a high ratio. I do not know whether this should be ascribed to the tropical climate influencing life in the surface waters or to the properties of the deeper water in the deep, land-locked basins or to some other factor.

Of the 5 samples of which the upper and lower end were analysed separately, 4 show the decrease of organic content going downwards. But the one exception more than compensates this tendency for the carbon, as may be seen in table IV.

TABLE IV.

Station	lower ends		upper ends	
	nitrogen	carbon	nitrogen	carbon
167	0.030	0.40	0.050	0.66
189	0.125	1.66	0.150	1.70
203	0.060	0.76	0.080	0.82
330	0.240	2.74	0.290	2.90
331	0.160	2.58	0.120	1.36
average	0.123	1.63	0.138	1.49

[1]) Trask, P. D. and Hammer, H.E.: Organic content of sediments. Drilling and Production Practise, 1934 (Amer. Pet. Inst.) pp. 117—130.
Idem: Degree of reduction and volatility as indices of source beds. ibid, 1935, pp. 250—266.
Trask, P. D.: Studies of source beds in Oklahoma and Kansas. Bull. Amer. Ass. Petr. Geol. 21, 1937, pp. 1377—1402.

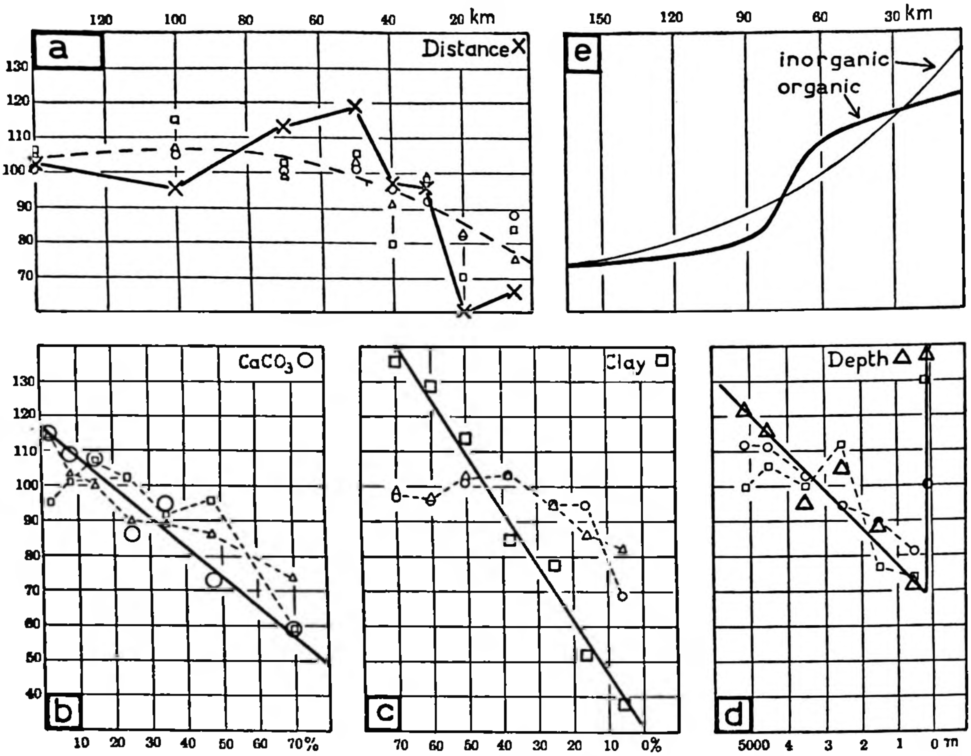

Fig. 3. a—d, The relation between organic matter (expressed in thousandth parts of a percent of nitrogen) to distance to the coast, lime, clay and depth. The larger points and thick lines appertain to the property given in the upper corner of each figure, the smaller points and dotted lines were found from the other diagrams (see explanation in text). e, Diagram showing the possible variation in rate of accumulation of inorganic and organic matter (drawn to different, arbitrary, vertical scales) with distance to the coast, in an attempt to explain the graph in a.

The clearest indications are found for clay (particles smaller than 0.005 mm). The points spread only slightly from the average line. Between 45 and 70 percent of clay the nitrogen rises from 0.050 to 0.140, while the lime content and depth of the groups of samples would have caused only a rise from 0.090 to 0.098. In other words: the influence of the percentage of clay on the organic content cannot be explained by assuming that it is secondary and merely a consequence of a relation between the grain size and the lime content, the latter then being the prima causa. Combining the two results, that the influence of grain size is to a large extent independent of other factors, and that it causes the greatest variations of nitrogen, I am strongly inclined to consider the percentage of clay as the dominating factor. True, there is a marked rise of lime with the falling off of clay below about 20 percent, but it does not appear likely that the influence of lime as such plays a major part for a short distance along an otherwise perfectly straightforward relation between clay and organic content.

The graph clearly shows, however, that the amount of clay is by no means the only influence at work, for at 0% clay there is still 0.030 nitrogen. In other words: under conditions in which no clay particles are deposited, there is still some organic matter preserved in the bottom samples.

When lime and depth in fig. 3b and d are considered we find an almost perfect correlation between these two factors. This is not surprising for the relation is one of the clearest in the East Indian sediments. (The matter is somewhat complicated as will be pointed out below). With increasing depth there is a fall in lime percentage and consequently the depth-points follow the lime-line on fig. 3b, and the lime-points the depth-line in fig. 3d, while in fig. 3c they follow one another. In the graphs there does not appear to be any indication which of the two factors is of more importance.

But the lines do appear to run slightly steeper than do the series of secondary points of depth and of lime. From this it would follow that lime and depth both have a slight, separate influence.

When the secondary clay-points are considered we find a course crossing over in a slightly more horizontal trend. We may conclude, that lime and depth are in closer relation with eachother than with clay. Also that they are somewhat less important than clay, because the clay-points are in closer agreement with the lime- and depth-lines, than are lime- and depth-points with the clay-line. In fact it would appear that the rising content of organic matter with falling $CaCO_3$ and increasing depth is partly due to a parallel drop in grain size. The latter influence, however, does not explain the whole correlation between lime or depth with organic content. Below 40—50 percent of lime and deeper than 2000—3000 m the grain size is no longer related to the other two factors and can therefore not explain the continued rise of the lines.

The very marked influence of clay is probably due not only to its conserving influence on the organic matter and to its occurrence in environments that are also favourable to the sedimentation of organic matter, but possibly also to a smaller rate of sedimentation of inorganic matter. Moreover, the clay appears to contain organic matter derived from the land (see page 20).

The influence of lime may be as follows. The calcareous tests are large particles and act as coarse sedimentary matter. In this respect they are the counterpart of clay particles. But the continued correlation below 40 percent, where the grain size has become constant, must be explained by an additional influence. This influence may be the solution of lime by which the organic matter is concentrated in a smaller remaining part of sediment. If the same amount of organic matter and terrigenous sediment were deposited at all points and lime merely acted as diluting agent, then the lime line should run straight to 100 percent $CaCO_3$ at 0 percent nitrogen. This line is seen to be steeper than the lime line. This proves that together with the calcareous tests a certain amount of organic matter is sedimented; roughly 0.030 percent of nitrogen in pure calcareous ooze. This is in good accordance with the graph for clay. Pure calcareous deposits will generally contain no particles of clay-dimentions and their 0.030 percent of nitrogen should therefore correspond to the amount found for 0 percent clay; and this is seen actually to be the case.

Concerning the relation between organic matter and depth little need be added to what has already been stated. Attention should only be drawn to the very striking increase of organic matter in the shelf-deposits. This is doubtless largely due to the high percentage of clay on the Soenda-shelf, as indicated by the almost perfect correlation between the organic content actually found (about 0.140 [1])) and the secondary point (0.130) corresponding to the average clay percentage of the samples, namely 63.

The relation between organic content and distance to the coast is less clear (fig. 3a). Planktonic life is on the whole more intensive closer in shore on account of a greater supply of nutritious salts. A priori one would expect to find a correlation of organic content and distance to the coast and Trask did actually find a decrease away from the land. When the points for lime, clay and depth are added in our graph we find that they cluster along a curved line, rising from 0.075 at the coast to 0.105 at 70 km off shore, followed by a horizontal continuation. In a general way the points for distance also follow this line. The variation of organic matter with distance from the coast is evidently largely due to the gradual change in lime, clay and depth as we proceed from the coast out to sea. It is less certain whether the distance has an independent influence. Close in shore the points are well below the line; at 50 km there is a peak and at 100 km a deep drop. These extremes may be due to the insufficient number of samples, but the general impression is that they are real. This would imply, that at the coast the nitrogen is 0.020 lower, at 50 km 0.020 higher and at 100 km 0.010 lower than it would have been, had the distance only had the secondary influence of changing lime, clay and depth. This direct influence of the distance could be accounted for in the following manner. The rate of sedimentation of inorganic matter decreases away from the coast, as does also the rate of production of organic matter. But the curve representing the former is probably slightly concave upwards, while the latter is perhaps characterised by a curve with a sharp drop at about 80 km. In fig. 3e these two curves are drawn to different scales so that they overlap.

On account of the uncertainty of the curve for distance and its irregular shape, it is not permissible to add points taken from this curve, to the graphs of fig. 3b, c and d.

[1]) $^1/_4$ was subtracted because these analyses belong to the older set (see page 20). For one of the stations without data on the lime and clay the average was taken of its two neighbours.

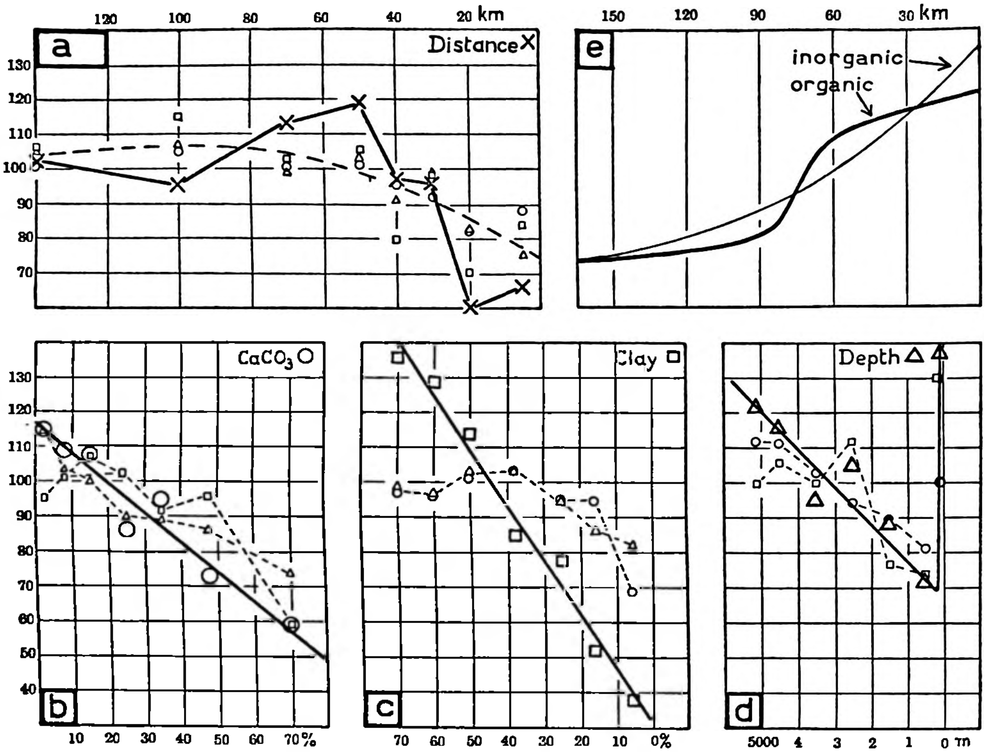

Fig. 3. a—d, The relation between organic matter (expressed in thousandth parts of a percent of nitrogen) to distance to the coast, lime, clay and depth. The larger points and thick lines appertain to the property given in the upper corner of each figure, the smaller points and dotted lines were found from the other diagrams (see explanation in text). e, Diagram showing the possible variation in rate of accumulation of inorganic and organic matter (drawn to different, arbitrary, vertical scales) with distance to the coast, in an attempt to explain the graph in a.

The clearest indications are found for clay (particles smaller than 0.005 mm). The points spread only slightly from the average line. Between 45 and 70 percent of clay the nitrogen rises from 0.050 to 0.140, while the lime content and depth of the groups of samples would have caused only a rise from 0.090 to 0.098. In other words: the influence of the percentage of clay on the organic content cannot be explained by assuming that it is secondary and merely a consequence of a relation between the grain size and the lime content, the latter then being the prima causa. Combining the two results, that the influence of grain size is to a large extent independent of other factors, and that it causes the greatest variations of nitrogen, I am strongly inclined to consider the percentage of clay as the dominating factor. True, there is a marked rise of lime with the falling off of clay below about 20 percent, but it does not appear likely that the influence of lime as such plays a major part for a short distance along an otherwise perfectly straightforward relation between clay and organic content.

The graph clearly shows, however, that the amount of clay is by no means the only influence at work, for at 0% clay there is still 0.030 nitrogen. In other words: under conditions in which no clay particles are deposited, there is still some organic matter preserved in the bottom samples.

When lime and depth in fig. 3b and d are considered we find an almost perfect correlation between these two factors. This is not surprising for the relation is one of the clearest in the East Indian sediments. (The matter is somewhat complicated as will be pointed out below). With increasing depth there is a fall in lime percentage and consequently the depth-points follow the lime-line on fig. 3b, and the lime-points the depth-line in fig. 3d, while in fig. 3c they follow one another. In the graphs there does not appear to be any indication which of the two factors is of more importance.

But the lines do appear to run slightly steeper than do the series of secondary points of depth and of lime. From this it would follow that lime and depth both have a slight, separate influence.

When the secondary clay-points are considered we find a course crossing over in a slightly more horizontal trend. We may conclude, that lime and depth are in closer relation with eachother than with clay. Also that they are somewhat less important than clay, because the clay-points are in closer agreement with the lime- and depth-lines, than are lime- and depth-points with the clay-line. In fact it would appear that the rising content of organic matter with falling $CaCO_3$ and increasing depth is partly due to a parallel drop in grain size. The latter influence, however, does not explain the whole correlation between lime or depth with organic content. Below 40—50 percent of lime and deeper than 2000—3000 m the grain size is no longer related to the other two factors and can therefore not explain the continued rise of the lines.

The very marked influence of clay is probably due not only to its conserving influence on the organic matter and to its occurrence in environments that are also favourable to the sedimentation of organic matter, but possibly also to a smaller rate of sedimentation of inorganic matter. Moreover, the clay appears to contain organic matter derived from the land (see page 20).

The influence of lime may be as follows. The calcareous tests are large particles and act as coarse sedimentary matter. In this respect they are the counterpart of clay particles. But the continued correlation below 40 percent, where the grain size has become constant, must be explained by an additional influence. This influence may be the solution of lime by which the organic matter is concentrated in a smaller remaining part of sediment. If the same amount of organic matter and terrigenous sediment were deposited at all points and lime merely acted as diluting agent, then the lime line should run straight to 100 percent $CaCO_3$ at 0 percent nitrogen. This line is seen to be steeper than the lime line. This proves that together with the calcareous tests a certain amount of organic matter is sedimented; roughly 0.030 percent of nitrogen in pure calcareous ooze. This is in good accordance with the graph for clay. Pure calcareous deposits will generally contain no particles of clay-dimentions and their 0.030 percent of nitrogen should therefore correspond to the amount found for 0 percent clay; and this is seen actually to be the case.

Concerning the relation between organic matter and depth little need be added to what has already been stated. Attention should only be drawn to the very striking increase of organic matter in the shelf-deposits. This is doubtless largely due to the high percentage of clay on the Soenda-shelf, as indicated by the almost perfect correlation between the organic content actually found (about 0.140 [1])) and the secondary point (0.130) corresponding to the average clay percentage of the samples, namely 63.

The relation between organic content and distance to the coast is less clear (fig. 3a). Planktonic life is on the whole more intensive closer in shore on account of a greater supply of nutritious salts. A priori one would expect to find a correlation of organic content and distance to the coast and Trask did actually find a decrease away from the land. When the points for lime, clay and depth are added in our graph we find that they cluster along a curved line, rising from 0.075 at the coast to 0.105 at 70 km off shore, followed by a horizontal continuation. In a general way the points for distance also follow this line. The variation of organic matter with distance from the coast is evidently largely due to the gradual change in lime, clay and depth as we proceed from the coast out to sea. It is less certain whether the distance has an independent influence. Close in shore the points are well below the line; at 50 km there is a peak and at 100 km a deep drop. These extremes may be due to the insufficient number of samples, but the general impression is that they are real. This would imply, that at the coast the nitrogen is 0.020 lower, at 50 km 0.020 higher and at 100 km 0.010 lower than it would have been, had the distance only had the secondary influence of changing lime, clay and depth. This direct influence of the distance could be accounted for in the following manner. The rate of sedimentation of inorganic matter decreases away from the coast, as does also the rate of production of organic matter. But the curve representing the former is probably slightly concave upwards, while the latter is perhaps characterised by a curve with a sharp drop at about 80 km. In fig. 3e these two curves are drawn to different scales so that they overlap.

On account of the uncertainty of the curve for distance and its irregular shape, it is not permissible to add points taken from this curve, to the graphs of fig. 3b, c and d.

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[1]) $^1/_3$ was subtracted because these analyses belong to the older set (see page 20). For one of the stations without data on the lime and clay the average was taken of its two neighbours.

In the foregoing analyses the 16 determinations cited in Trask's book have been neglected. The reason was that they show a systematic divergence from the later determinations. One sample, station 119, was used in both sets of determinations. In the first set the nitrogen was given as 0.120, in the second set as 0.060. Whether the average nitrogen percentage is considered, or the relation with lime, clay or depth, we always find a percentage that is roughly $^1/_3$ too high, even when the three samples of less than 100 meters depth and the exceptional sample of station 107 are discarded. When $^1/_3$ is subtracted from the nitrogen, the older values fit onto the new ones quite well. I cannot say whether this divergence is due to a different treatment, before or after the samples were received by Dr. Trask, or to the fact that they were a few months old when analysed, instead of a few years[1]). The grounds for distrusting the older determination appear sufficient for discarding them when drawing the graphs.

Miss Neeb offered the suggestion, that the organic matter may also be in part of terrigenous origin and carried to sea forming part of the clay particles. In support of this notion she calls attention to the low organic content of the volcanic muds and typical Globigerina oozes, low in clay content, material that was never covered by vegetation. She further points out that according to Hardon [2]) the organic matter in tropical soils is chiefly contained in the silt and clay fractions. The percentage of nitrogen increases with sinking percentage of sand. In well over 1000 samples the C/N ratio varied between 10.71 and 15.35, values that accord with those of our deep sea samples.

With a view to testing this suggestion the following estimates can be made. River mud of the Javanese streams contains some 2.9% organic matter according to den Berger. [3]), a percentage that would roughly correspond to that of the soil in the regions above stream of the points where samples were collected. For the Molucca's a larger amount, 5%, of organic matter in the river muds may be expected (see Hardon's figures on the primeaval forest soil, 5—6%). As the sediments of the Moluccas contain 2% and as not all this material is derived from the land as silt and clay, the percentage with relation to the fine terrigenous material is about half the original content of the river muds. During the many years the fine particles travel through the sea water before being deposited, the organic matter is subjected to oxydation and to washing. A very considerable loss is to be expected, yet no or only slight surplus from the river mud is available. On the other hand the yearly production of organic matter in the surface layers of the sea is also a possible source for the organic content of the deposits. It is of the order of 1000 grams per m^2 [4]). The original organic content of the river mud deposited on the same area works out at only 10 or 20 grams. A large proportion of the planktonic production is destroyed before it settles on the bottom, principally by animal consumption. In view, however, of the fact that the local production is some 50 to 100 times as great as the contribution from the land, I am of opinion that in spite of greater loss the planktonic contribution outweighs that from the land. This is in accordance with the deduction reached above that deposits without clay still contain an appreciable amount of organic matter. *Possibly*, however, the bulk of organic matter in the sediments is derived from the land, as Miss Neeb suggests, an important point to be held in mind during future investigations.

Miss Neeb is of opinion, that the low percentage on Globigerina ooze militates against the derivation of organic matter from the plankton. The shells would offer protection and thus cause a high percentage of organic matter when massed together in the sediment, if the organic content of bottom samples were due to production in the surface layers of the sea. In my opinion it is equally probable, that the low percentage is due to the currents along the bottom, that we must postulate in localities where the clay fraction is poorly represented in the deposits. The slow accumulation and pervious nature of the deposit and the constant current sweeping the bottom may in my opinion account for the low organic content of Globigerina ooze, even if it is assumed that all organic matter in deep sea deposits is of planktonic origin.

In conclusion it should be pointed out, that the lines for lime, clay and depth have been drawn

[1]) On page 24 Trask gives reasons for supposing that ageing has no influence. He now kindly informs me, that he is also inclined to assume some decomposition with age of samples stored in wet condition, as ours were.

[2]) H. J. Hardon, Factoren, die het organische stof- en stikstofgehalte van tropische gronden beheerschen Landbouw XI, 1935/36, 517—540.

[3]) L. G. den Berger en F. W. Weber: Verslag van de water- en slibonderzoekingen van verschillende rivieren op Java. Med. Alg. Proefst. v. d. Landbouw, No 1, Batavia 1919.

[4]) P. D. Trask, Organic Content of Recent Marine Sediments. Symposium on Recent Marine Sediments, 1939, pp. 428—453.

straight, but that they may actually be slightly curved. More data would be needed to ascertain their exact course.

This type of investigation would be more satisfactory if there were sufficient determinations to consider the various basins of the East Indies separately. It would then also be possible to take into account the regional distribution of the organic content in the sediments and to investigate the various types of deposit separately.

All that can be brought forward concerning the regional distribution is, that four (st. 229, 230, 325, 324) (five? st. 107) values above 0.200 percent nitrogen fall in the Boeroe-Ceram trough to the north of these islands (doubtfull high value to the south east of the Tenimbar islands) see fig. 2. There is one very high value in the Weber-deep north of the Tenimbar islands (st. 346a) and another in the Halmahera basin (st. 353).

High are stations 305 in the Celebes-sea, st. 189 in the Gulf of Boni, st. 317a north of Flores, st. 328 again in the Ceram trough. The following stations have a high value, especially when the lime, clay and depth are taken into account: st. 216, 253, 360, 322, 117; and only moderately high: st. 303, 347, 350, 212, 209, 361, 368, 346, 203.

Finally there are the high values on the Soenda-shelf and opposite the Mahakam river in eastern Borneo [1]). Apart from these high figures for shelf-sediment, the only definite conclusion is that the Boeroe-Ceram trough is also exceptionally rich in organic matter.

In the abnormally low values there does not appear to be any regularity as to distribution.

Petroleum Geology

Naturally one would wish to know what light is thrown on the problems of petroleum geology by our samples. But most mineral oil comes from shallow water environment, therefore from different facies than we have examined. In how far the relations established by us also hold for shallow water conditions is doubtful. Oil is a very common product in geosynclinal deposits. Although there may be exceptional source bends, the greater part of petroleum must have been formed from normal deposits. If in tropical environments the same relation between organic matter and lime or clay exists in shallow waters, as there does in deep basins, than we may expect that in general the finer deposits and those poor in $CaCO_3$ are the source beds.

The increase of organic content with depth is at first sight surprising. The rocks of oil pools are supposed to have been laid down in shallow water, whereas we are led to suppose that the small depth is unfavourable to the accumulation of organic matter. We have seen, however, that depth *alone* has little influence, for the apparent influence is partly due to the variation of lime with depth, but principally to the parallel variation of grain size.

In other words our results lead one to expect, that in shallow, tropical basins of large extent relatively high percentages of organic matter need not be exceptional, provided the sediments are fine and not too high in lime content.

We must now compare our results with those of Trask. Owing to the reasons given above it is inadvisable to compare the absolute values in his book with the new determinations. Still the East Indian region is evidently not rich in organic matter, as the average is 0.10 percent of nitrogen and Trask considers less than 0.15 as poor and more than 0.30 as rich. The Boeroe-Ceram trough is the richest environment in the East Indies, but is not more than moderate when compared with sediments in general.

Trask found the same correlation between grain size and organic content, namely most nitrogen in the finest sediments. The relation between grain size and configuration, a subject on which we also owe important data to the same investigator, will not be dealt with in this chapter. Our own data are too scarce to ascertain whether configuration has a direct influence on organic matter apart from the relation to grain size.

On p. 108 Trask states, that in a general way there is no close correlation between organic matter and $CaCO_3$. In some regions he even finds a variation of the nitrogen in the same sense as the quantity of carbonate; the opposite to our results for the East Indies.

[1]) Miss Neeb's suggestion that most of the organic matter is carried to sea by rivers is supported by the latter sample.

On p. 118 he says: „The organic content of the sediments, from the coast seaward, is more or less constant for 100 miles, between 100 and 500 miles it diminishes rapidly, and at a distance of 500 miles it has decreased to the insignificant quantity of the mid oceanic regions".

The whole variation we find occurs within the 100 mile zone of Trask, as our greatest distance to the coast is exactly 100 miles. It is therefore better to compare our district with the Channel Islands Region off Southern California. Here Trask found the same increase with depth as we noted, at least in shallow water. However, he ascribes considerable influence to the configuration of the sea floor and gives convincing examples. He also explains the higher organic content (in spite of greater depth) of the basins lying further off-shore, to more pronounced upwelling and consequent greater growth of plankton (p. 123). I imagine that it might be due to a similar peak, as is suggested by the values in our fig. 3.

2. Relation between the organic content of the bottom samples and the oxygen content of the bottom water

There does not appear to be any connection between the amount of organic matter contained in the deposits on the sea floor and the percentage of oxygen in the overlying water.

The bottom samples were divided into two groups: those containing 0.100 and more percent of nitrogen and those with less. The oxygen content of the bottom water sample and the lowest sample of the serial observations was averaged for each station. It was found that the water over the first group of deposits averaged 2.50 and over the second 2.48 cc O_2 per liter. This difference is negligeable, so that the absolute amount of organic matter in the ooze and of oxygen in the water are in general independent factors [1]).

The nitrogen percentages were also compared with the O_2 determinations obtained at stations where multiple bottom water samples had been taken. Again a negative result ensued. At station 66 a strong decrease of O_2 in the water was found towards the bottom, but the nitrogen of the deposit was 0.110, a value close to the average (the average is 0.100). At station 80 the O_2 decrease was slight and the nitrogen was rather low (0.085). At station 374 the nitrogen was low (0.060) and at station 330 it was high (0.290) but at neither was there a decrease of O_2 towards the bottom.

Only at one of the stations where the bottom water sample shows a distinct drop, did the organic content of the deposit happen to have been determined. The deep sea oozes therefore give no indication whether that drop is due to natural conditions or to oxydation of the inner surface of the water sampler.

B. CHEMICAL BULK ANALYSES

Miss C. Koomans kindly performed 6 chemical analyses of different types of deposit. The results are given in the adjoined table. The dried material was examined directly without extracting the sea salts. The amount of these, however, is inappreciable considering the inhomogeneity of the samples, except for Cl. and Na. The former is entirely derived from the sea water. For Na_2O the correct amount, as deduced from the chlorine, has been added to the table. As no separate determinations were made of the portion of Mg bound to CO_2 the degree of dolomitisation cannot be ascertained. Amorphous SiO_2 includes siliceous tests.

A separate column has been added giving the average of all six samples. The composite analysis may give a rough impression of the average composition of the sediments in this region, although the number of samples is too small to be of much value.

Some interesting points call for attention. The high value for CaO shows that our average is rich in lime. Taking this into account the low K_2O is normal, but the Na_2O is very high. According to Clarke the average for blue muds is 1.05 and of Globigerina ooze 0.98 [2]). We find $1^1/_2$ times this amount. TiO_2 is low. All other elements show normal percentages for the type of sediment.

At the bottom of the table the percentages of $CaCO_3$ as determined by Dr. Hardon at Buitenzorg have been included. It will be seen, that there are comparatively large discrepancies in some cases, probably due to irregularity of the samples.

[1]) The case of the Kaoe bay is exceptional as anaerabic conditions have developed in the deeper waters.
[2]) F. W. Clarke: The Data of Geochemistry. Bull. 770, U.S. Geol. Surv. 1924.

TABLE X.

Station	290	360	169	361	215	364	average
Type of deposit							
SiO_2	30.49	48.94	40.46	37.30	46.21	4.26	34.61
TiO_2	0.04	0.08	0.48	0.40	0.21	—	0.20
P_2O_5	0.38	0.30	0.18	0.17	0.21	—	0.21
Al_2O_3	8.56	14.18	18.53	15.75	18.62	2.75	13.07
Fe_2O_3	3.32	1.58	7.05	2.74	3.82	0.47	3.16
FeO	1.76	3.17	3.13	2.16	2.18	—	2.07
MnO	0.34	0.26	0.35	0.14	0.18	—	0.21
MgO	1.38	2.00	4.37	2.18	2.49	0.42	2.14
CaO	23.00	8.31	8.50	10.74	5.52	50.30	17.73
Na_2O	2.65	1.53	3.94	3.13	3.02	0.69	
N_2O minus salts	(1.86)	(0.69)	(2.95)	(2.44)	(1.88)	(0.04)	(1.64)
K_2O	1.11	1.97	1.54	2.46	1.86	0.27	1.53
$+H_2O$	3.62	5.06	2.19	4.21	4.43	1.57	
$-H_2O$	2.28	1.55	2.31	2.45	2.14	—	
CO_2	16.11	5.83	2.77	7.31	2.57	39.33	12.32
Cl_2	1.05	1.12	1.32	0.92	1.52	0.86	
amorphous SiO_2	4.35	4.39	3.24	8.57	5.67	—	4.37
	100.44	100.27	100.36	100.63	100.65	100.06	
O_2-substraction for Cl_2	0.24	0.25	0.30	0.21	0.34	0.19	
	100.20	100.02	100.06	100.42	100.31	99.87	
$CaCO_3$ Hardon	44.0	15.6	7.6	13.9	7.6	89.6	

C. PERCENTAGE OF CALCIUM CARBONATE

Slope and distance to coast

We will now turn to the influence of coastal distance and bottom slope, on the percentage of Calcium Carbonate.

TABLE XI. Relation of Calcium Carbonate Content of Sediments to Depth of Water in the East Indies.

Depth in meters	Number of samples	$CaCo_3$ Percentage	Southern Sulu Sea	Snellius Samples Slope > 5°: Number of samples	Percentage $CaCo_3$
0— 500	44	43.7		5	62
500—1000	42	39.3		9	33
1000—1500	39	37.7		16	35
1500—2000	34	31.3	67	10	29
2000—2500	34	23.2		3	22
2500—3000	38	25.6		11	33
3000—3500	21	17.9		5	30
3500—4000	17	14.3	65	2	20
4000—4500	13	10.2	65	4	7
4500—5000	9	10.9		0	—
5000—5500	13	2.1		1	1
> 5500	10	4.4			
	Average	22		Average	27

TABLE XII.

Depth in Meters	Distance form Shore in Kilometers			
	0—30	31—60	61—100	> 100
	Calcium Carbonate Content; Percentage			
0—1500	39.6 70 samples	40.0 29 samples	30.1 17 samples	64.8 9 samples
1500—3000	25.0 21 samples	21.4 38 samples	28.7 23 samples	33.0 15 samples
> 3000	16.4 19 samples	6.3 22 samples	7.7 18 samples	7.0 27 samples
	0—20 km; 23.7 6 samples			

In Table XII data on the depth, distance from shore, and calcium carbonate content of the Snellius and Siboga samples are presented. The result is curious.

In shallow areas the percentage increases with distance from shore, although the number of samples is not large enough to rule out fluctuations. For moderate depths the table indicates only a slight increase away from shore. For deeper regions, however, the lime content decreases seawards. The higher percentage of $CaCO_3$ near shore is even more marked when a narrower zone of only 20 kilometers is considered.

The decrease in the shallower parts towards the coast must result from diluting by denudation products, in the manner Böggild pointed out. That the conditions are reversed when deeper regions are considered shows that a new factor is introduced. It appears probable that this factor is the slumping of sediments down a sloping bottom.

The closer deep water lies to shore, the greater must be the slope of the bottom. As soon as this slope becomes more than a few degrees the deposits start to slide down the slope bringing shallow-water sediments down to greater depths. If this transportation is of an intermittent character solution will not be able to decalcify a newly deposited stratum and a percentage of carbonate will remain, greater than that of deposits laid down gradually in situ along a flat bottom at the same depth.

Some indication that sliding does actually take place and influences the lime percentage is to be found in the last two columns of table XI. The average percentages of carbonate are given for samples taken where the bottom slopes more than 5°. The slopes were measured from the echo-sounding sections. The average percentage of $CaCO_3$ is increased from 22 percent for all samples to 27 for those on a slope. The main influence exerted by a slope on the deep-sea oozes is the help given to the sliding of carbonate-rich sediments into deeper regions, where a lower percentage would prevail if the deposits had gradually accumulated in situ.

D. RADIUM ANALYSES

R. D. Evans with the collaboration of A. F. Kip published radioactive analyses of a few Snellius samples in 1938 [1]). The results are repeated here with a few brief comments. Besides 5 of our samples, he also investigated 2 specimens of the famous fossil red clay from Noil Tobee, Niki Niki on Timor and some of the enclosed manganese nodules. The results are as follows.

[1]) Evans, R. D. and Kip, A. F.: The Radium content of marine sediments from the East Indies, the Philippines, and Japan, and of the mesozoic fossil clays of the East Indies. Amer. Journ. Sc. Vol. XXXVI, 1938, pp. 321—336.

TABLE XIII.

Sample	Depth	Determination	g Ra × 10^{-12} per g
331	5050	terrigenous mud, principally detritus of acid eruptive rocks.	2.36
303	4450	terrigenous and volcanic mud.	2.47
301	5200		2.73
262	10050	terrigenous mud, detritus of calc– alkali rocks and .	1.38
265	4950	slightly metamorphic rocks	1.76
325	specimen	Upper-cretaceous red clay.	0.264
327	„	„ „ „	0.579

Evans added the remark that the five recent deposits all show a characteristically high radium content, such as is usually associated with deep-sea deposits from the ocean basins. Terrestrial sedimentary rocks ordinarily contain about 0.2 to 0.8 × 10^{-12} g Ra per g. It is noteworthy that the samples from the Mindanao trough 262 and 265 have slightly lower values. Specimen 325 of the fossil red clay was from the lower, reddish stratum at the bottom of the exposure, that contains large manganese nodules and the enamel of sharks' teeth. The specimen 327 came from the upper brownish layer containing small, crushed manganese nodules. This is not the place to enter into a discussion of the true nature of the red clays from Timor. They have been fully described by Molengraaff [1]) who showed that the chemical composition, the general appearance, the partly dissolved fish teeth, the manganese nodules and the small thickness all tend to prove that we are dealing with true deep-sea deposits. We may add that the Mesozoic geosyncline of Timor contains other rocks indicating great depth. Thus I found at Noil Tobee a piece of silicified Halobia limestone, covered with a thick crust of manganese. There are also the thin Cephalopode limestones with manganese crusts and other similar rocks. Personally I am fully convinced of the deep sea nature of the red clays of Noil Tobee.

Evans points out, that the absence of a high radium content suggests that either they were originally formed in shallow water or else that uranium is not associated with the radium found in deep sea materials. Uranium, it should be remembered, disintegrates so slowly, that an upper-cretaceous sediment, some 100 million years old, should still be markedly radioactive if its original activity was due to this element. On the other hand a sample containing only Radium will have lost its activ long before it becomes of geological age.

As in my opinion the first possibility is ruled out, the second conclusion, also held by Evans, seems to me to be warranted.

A significant point must be raised here. Sedimentation must be considerably swifter in the Moluccan basins, than in the deep sea of the oceans. It can be shown that the terrestrial muds accumulate in these land-locked seas very quickly, probably at least 25 times as quickly as the blue muds of the central Atlantic, and in some localities almost 50 times. If the radioactivity of deep sea oozes were due to a kind of precipitation, of uranium oxyde independent of the sedimentation going on, as Piggot suggested, then the activity should be diluted in regions of swift accumulation [2]). The average of the 5 East Indian samples is 2.21 (× 10^{-12} g Ra per g), while that of 13 deep sea red clays was found

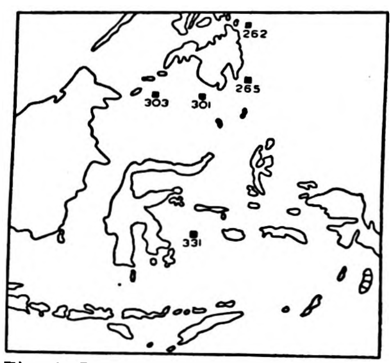

Fig. 4. Location of samples analysed for radioactivity.

[1]) Mangaanknollen in mesozoïsche diepzee afzettingen van Nederlandsch Timor. Versl. Wis- en Natuurk' Afd. Koninkl. Akademie van Wetenschappen, Amsterdam, 27 Nov. 1920. Deel XXIX, pp. 677—692.

[2]) C. S. Piggot: Radium content of ocean-bottom sediments. Amer. Journ. Sc. Vol. XXV, 1933, pp. 229—238.

by Piggot to be 9.5 or only about 4 times as much. If the precipitation of radioactive elements took place in the manner Piggot proposed, one would expect either red clays to be much more radioactive, or that the East Indian blue muds showed a figure comparable to that of fossil sedimentary rocks from shallow environments, that is 0.2—0.8.

The alternative view that accounts better for the facts, is that the radioactivity is a property of the sedimentary particles themselves. Then the rate of accumulation will have no influence on the degree of activity and that is evidently the case.

Evans was able to show [1]), that the activity of a shallow water sediment (276 m) from California was mainly concentrated in the finer particles, namely those smaller than 50 microns. If this were a strict rule, the finest of the East Indian samples, 262, should have the highest activity, but it happens to be the lowest. (1.38). By far the coarsest sample is 265 (47% > 50μ), and its radioactivity (1.76) is somewhat below the average (2.24).

Each of the East Indian samples is above the radioactivity of the highest value in Evans' sample (1 — 3 μ = 1.31). This bears out the conclusion that size of particles is not the only factor. Neither did Piggot find more activity in the finer fraction of a deep-water sample.

It might be thought then, that depth is the dominant factor producing a high activity. But in that case our sample 262 from just over 10.000 m should beat all records. Actually it is the poorest of all five.

From Piggot's data the following averages are found.

0 — 3000 m (5 samples) 2.90 × 10^{-12} g per g
3 — 4000 m (7 ,,) 5.54 ,,
4 — 5000 m (9 ,,) 8.58 ,,
5 — 6000 m (7 ,,) 7.45 ,,

This shows a certain amount of increase with depth, though not a close correlation.

Many of the clay particles in shallow water sediments have been in the water for a considerable time (having been stirred up repeatedly, before ultimately coming to rest) and therefore no shorter than the particles in deep-sea oozes. The length of time a particle floats in sea water is therefore not of much consequence. Otherwise we might suppose, that the stronger activity of deep-water samples were due to their long contact with the water. The tentative conclusion drawn by Evans on a series of analyses of water from different depths, is of an increase in radioactivity with depth. If this is found to be a general rule the supposition could be made, that the fine clays absorb radioactivity from the water, and become increasingly active the deeper they have sunk. The finer a sediment and the deeper the bottom, the greater the radioactivity would be, irrespective of the rate of accumulation. Scattering of values for individual analyses must be assumed to account for exceptions to the rule.

Evans suggested that the particles showing the high radioactivity might be those derived from organisms.

However, Piggot has already pointed out that the average radioactivity for 27 red clays was 12,1 and for 13 Globigerina oozes 4.1 although the former are predominantly mineral in composition. As deep sea deposits are markedly poorer in organic matter than shallow water sediments, neither the tests nor the organic matter can be held responsible for the high activity of deep sea deposits.

The analysis by Evans appears to be the only one made of a recent (not fossil) shallow water sediment. One requirement for elucidating these problems is for more data on samples from the shelf.

E. WATER CONTENT

For various purposes, such as calculating the rate of sedimentation or for geochemical deductions, the percentage of water in the deposits must be known. Correns determined the moisture of his samples long after they had been removed from the glass tubes. Thus part of the water had probably evaporated. The average of his determinations is about 45% by weight.

No measurements had been made on the Snellius samples until 12 years after the expedition [2]).

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[1]) R. D. Evans, A. F. Kip and E. G. Moberg: The Radium and Radon Content of Pacific Ocean Water, Life, and Sediments. Amer. Journ. Sc. Vol. XXXVI, 1938, pp. 241—259.

[2]) The moisture was determined in the air-dried samples by Dr. Hardon and the figures are included in the table in Section II. But that is quite a different problem to the one dealt with here.

By that time many of the samples had been entirely used for other determinations, or had dried out for some reason or other. Several samples, however, appeared to be still in good condition and to have lost only negligeable amounts of water. Of these a small portion was taken from the upper and lower ends and the moisture determined by weighing before and after drying at 105° C. The results were rather puzzling, for while without exception the upper ends were as soft and generally softer than the lower ends when the tubes were opened, a higher percentage of water was found in the lower ends of several samples. The consistency thus clearly showed the results of compaction and cementation, while yet the moisture content frequently increased downwards. The samples had stood upright for most of the time since the expedition. The subjoined table shows the results.

The average of the 22 determinations is 58% of water by weight [1]) or 75%—80% by volume. This shows, that the samples investigated by Correns had probably already lost 10% to 15% of the original moisture. But it is quite possible, that the Atlantic sediments contain considerably less moisture than the East Indian deposits, in consequence of the nature of the material or of the slower sedimentation.

TABLE XIV.

Water content of some samples

station	part of sample	determination	percentage water of wet sample
St. 26	0— 4 cm	Terrigenous mud	57
„ 26	40— 43 „	probably partly fossil sediment	54
„ 30	0— 4 „	Terrigenous mud	62
„ 30	46— 50 „		67
„ 66	0— 4 „	Globigerina ooze	55
„ 66	44— 48 „		61
„ 121	0— 4 „	Terrigenous mud	61
„ 121	10— 14 „		62
„ 121	48— 52 „		60
„ 248	0— 4 „	Globigerina ooze	59
„ 248	76— 80 „		53
„ 248	80— 84 „		59
„ 278	0— 4 „	Terrigenous mud	70
„ 278	164—168 „		55
„ 331	50— 54 „	Terrigenous mud	59
„ 331	177—181 „		65
„ 333	0— 4 „	Terrigenous mud	68
„ 333	55— 59 „	with small admixture of volcanic mud	59
„ 347	6— 10 „	Volcanic mud	45
„ 347	86— 90 „		58
„ 347	120—124 „		45
„ 347	170—174 „		53
22 samples		average	58

[1]) Originally the average probably attained 60% or even more.

CHAPTER IV

MISCELLANEOUS ASPECTS OF SEDIMENTATION

A. ANAEROBIC SEDIMENTS OF THE KAOE BAY

During preparation of the program for the Snellius-Expedition I was struck by the peculiar submarine morphology of the bay between the two northern arms of the island of Halmahera. While the basin of the Kaoe bay is some 500 m deep and 60 by 30 km in extent, the broad entrance nowhere exceeds 50 m in depth. It appears almost certain, that during the low sea levels of the Ice Age, the threshold was laid dry and the Kaoe bay gradually converted into a fresh water lake. Somewhere below the recent marine sediments must be buried deposits bearing the mark of fresh water conditions. If these could be detected in our bottom samples, not only the lowering of glacial sea level could be proved, but the rate of subsequent sedimentation determined.

Realisation of the probability that the post-glacial deposits must be considerably thicker than the few decimeters found in the open Atlantic by Philippi, led me to construct the large, heavy sampler described in a previous chapter. The sampler functioned satisfactorily and brought up samples of 168, 148 and 128 cm length in the Kaoe bay. But although these samples were stratified the glacial deposits were evidently not represented among these layers and must lie still deeper. Subsequent experience, amongst others by Piggot and Stetson on the Atlantic slopes of North America, where post-glacial deposits of 1 m thickness and more were encountered, now renders obvious, that the corresponding sediments of the Kaoe bay may be many meters in thickness and the pleistocene strata far beyond the reach of any type of sampler so far developed.

The investigation of this curious basin has brought other facts to light, however, that are no less important. The oceanographers of the expedition expected to strike poorly ventilated waters and their predictions proved to be correct. When the large sampler was brought on deck it spread a strong smell of H_2S and the bottom water on analysis showed 0.30 cubic centimeters per liter. At 180 m depth the water contains less than 1 cubic centimeter of oxygen per liter. Our figure 5 shows an oceanographical section.

An excellent survey of what is known of the oceanographical conditions and sediments of badly ventilated basins was given by K. M. Strøm on p.p. 356—372 in the symposium on „Recent Marine Sediments" edited by P. D. Trask and published by the Am. Ass. Petr. Geol. in 1939. In Norwegian fjords, cut off from the open sea by shallow thresholds, the stagnant waters of the deep may contain many cubic centimeters of H_2S per liter, with a maximum of 40. The muds are black and the organic content may be as high as 23.4 per cent organic carbon. In other cases both in fjords and elsewhere the bottom waters are sufficiently ventilated to contain some oxygen, but the sediments nevertheless show a superabundance of organic substance and develop hydrogen sulphide. These muds, such as those off Walvis Bay in southwest Africa, are generally green.

Strøm stresses the point, that in all cases known the muds are black as soon as the bottom water contains H_2S. The upper stratum of the Black sea sediments should be excepted as these are coloured gray by the strong admixture of lime. (See P. D. Trask in the same symposium, p.p. 448—449). Now in this respect the sediments of the Kaoe bay form an exception. Although, as pointed out above, the deep water is deoxygenated, and thus black muds should be forming, the actual sediments are light green. Neither do they contain much lime,the percentage being on an average 15,4. They are nevertheless highly charged with hydrogen sulfide. Not only do they smell strongly of this gas, but on being lifted to the surface, thus undergoing a reduction of pressure of 50 atmospheres, they are broken up when pushed into the glass tubes by the development of gas bubbles. In this condition they are of a more or less spongy consistency. The amount of organic matter they contain is considerably higher than most of the other sediments of the East Indies (see the paragraph on organic

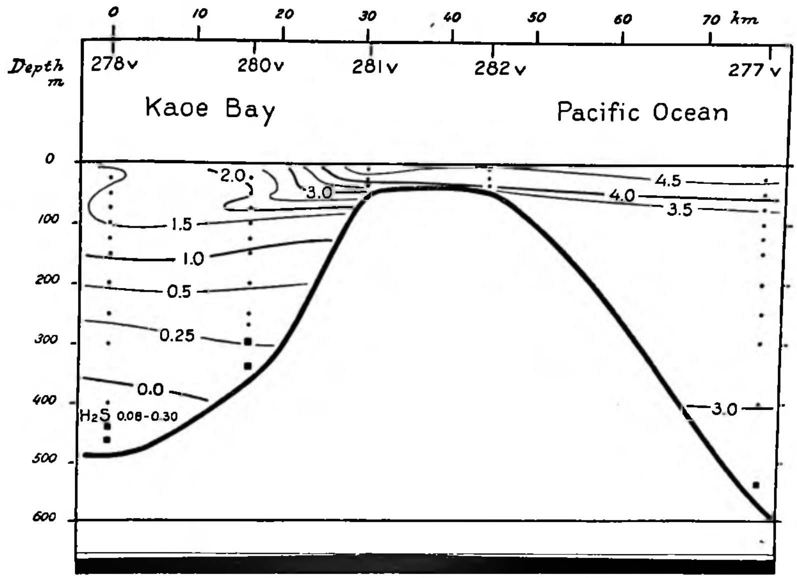

Fig. 5. The Kaoe bay in Halmahera. The deeper waters are polluted with H_2S.
Below natural scale.

content). Compared with the black sediments of the Norwegian fjords, however, they are rather poor in carbon.

Strøm points out that owing chiefly to the great regularity of the climate with small diurnal or yearly variations, stagnation of deep waters is more frequent within tropical regions than in temperate or arctic localities. Every basin in Norway for instance, with the topographic features of the Kaoe bay would, says Strøm, be fully ventilated.

The same author emphasises the difficulty of predicting what the oceanographical conditions in former periods of the earth's history will prove to have been. The fact that the sediment we encountered in the Kaoe bay is abnormal, and different to what could have been expected, serves to illustrate how careful one should be in concluding under what conditions fossil sediments were deposited. The extensive bibliography [1]) brought together by Strøm on interpretation of fossil sediments supposed to come from badly ventilated waters, shows how much speculation has already been expended on this subject. Evidently more oceanographical data are called for to establish the basis for such deductions, before much confidence can be felt in the conclusions drawn.

B. STRATIFICATION IN THE SAMPLES

For several reasons one would expect to encounter stratification frequently in the Moluccan region. In the first place the longer samples taken in the Atlantic ocean by Philippi, the Meteor-Expedition, Piggot and others almost all show two or more layers, generally a Globigerina ooze over red clay, the latter representing the last Ice Age. Secondly the lithified sediments encountered in geological field work seldom show thick layers. Finally the steep slopes, volcanic activity, the strong seismicity and the recent elevation of islands are all factors that might be expected to cause variations in the sediments and thus tend to further the development of strata. It is therefore surprising to find on examining the list of samples in Section II of this report, that clear or even vague strata are exceptional.

The following reasons may be given to account for this scarcity of stratification. Sediment must accumulate much more swiftly in these basins than in the wide Atlantic. The proximity of the coast,

[1]) See also: W. G. Woolnough: Sedimentation in Barred Basins, and Source Rocks of Petroleum. Bull. Am. Ass. Petr. Geol. Vol. 21, 1937, p.p. 1101—1157. E. Wayne Gulliber: The Sulfur Cycle in sediments. J. Sedim. Petrol., Vol. 3, 1933, pp. 51—63. G. Frebold: Der Stand des Problems der Entstehung des Mansfelder Kupferschiefers. Geol. Rundschau, 1924, p.p. 261—272.

the volcanic activity, the steep islands and the very active denudation must result in an abnormal ranspo rt of detritus to sea.

This expectation is born out by what Miss Neeb is able to show, namely that the sedimentation of terrigenous mud is at the very least ten times as fast as in mid-Atlantic. In a later paragraph it is shown, that the rate of denudation leads one to expect an average sedimentation some dozens of times that found by Schott in the centre of the tropical Atlantic.

Consequently it must be assumed, that the pleistocene deposits, that are cut by the sampler in the Atlantic, are so deeply buried below terrigenous matter in the East Indies as to lie beyond the reach even of our heavy sounding tube. In general the pleistocene strata are to be expected at a depth of several meters below the surface.

But even at sites where sedimentation is leasurely in consequence of currents sweeping the bottom and where the pleistocene deposits occur near the surface, it is doubtful whether they would show up as clearly as in the Atlantic Ocean. The Moluccan basins are effectively screened off from the deep ocean waters, and the climate of the Ice Ages does not appear to have been very different in these tropical regions. Conditions governing sedimentation will therefore not have varied nearly as strongly in our field of investigation as in the Atlantic. Miss Neeb's investigation of the Foraminifera did not disclose any variation with depth attributable to climatic pulsations, although she paid special attention to the question under discussion. This can be explained either, as she does, by assuming that the pleistocene strata were reached by the long samples, but that they are indistinguishable from the later deposits, or that the post-glacial stratum was too thick to be cut by the long sampler. Personally I am more inclined to the latter point of view. We will return to this subject in a later section (p. 32).

An explanation must also be offered, why most of our samples, many of nearly a meter length or even double that amount, are unstratified, while most ancient sediments met with during geological field work show considerably thinner layers. Thus Twenhofel in his Treatise on Sedimentation (2d edition, 1932, p. 666) states: „In general, the thickness of most units falls between 2 inches (= 5 cm) and 2 feet (= 60 cm)". It was already pointed out above, that the general conditions in the Moluccan region are exceedingly variable. One can hardly suppose that practically all basins in which fossil sediments collected, have had a far more variegated and eventful history. If absence of stratification in the deposits of the eastern part of the East Indies were to be looked upon as proving this region to be exceptionally equable, although the islands abound with marks of recent upheaval, of volcanic activity and seismic unrest, how hectic one would have to picture the history of a sedimentation trough such as the Parisian or London basins where individual strata seldom exceed a foot in thickness. I am convinced that the true explanation is to be sought in a different direction, namely the great depth of the troughs and basins.

Barrell was the first to emphasize the great importance of the recurrent interruptions of sedimentation [1]). He called these minor unconformities diastems and pointed out that in any sedimentary column the number of years represented by actual accumulation must be greatly outnumbered by the years during which there was a halt, or in which even a part of the deposits was again stirred up and carried elsewhere. The thicknesses of the strata in a basin are supposed by Barrell to be limited by the rate of sinking, not by the supply of detritus. In fact sedimentation is on the whole able to keep even swiftly sinking geosynclinal troughs brimful.

Quite different circumstances obtain in the East Indian basins, for the depth is so great, that neither waves nor powerful currents stir up the deposits and sedimentation continues uninterrupted year after year. In short, normally diastems are entirely absent from deep sea deposits and this must result in much less strata developing. The „hard bottoms" of the thresholds of East Indian basins, however, are the recent expression of diastems if they are not to develop into unconformaties.

Besides furthering the absence of interruptions in sedimentation the great depth has another unifying influence. It takes so long for particles to reach the bottom, that they are scattered far and wide and the sedimentation is spread out over so long a period, that all transitions from one type of sediment to another must be gradual in marked degree. This point is so important for understanding sedimentation problems, that it will be gone into more at length in the next paragraph.

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[1]) J. Barrell, Rhythms and the measurement of geologic time. Bull. Geol. Soc. Vol. Am., 28, 1917, pp. 745—904.

Finally the absence of coarse sedimentary matter must have a unifying influence and render the development of strata less pronounced.

I will not attempt to offer an explanation of the individual cases in which stratification did show up in the samples. The reader is referred to the list of samples and to Miss Neeb's treatment of this subject for further information. On plate II two examples of stratification are given, one of a few layers with gradual transitions, the other of coarse strata with pumice, due to volcanic eruptions, that show a sharp lower boundary and gradual merging into the normal sediments above. Most of the 25 stratified samples owe their layers to volcanic activity and several cases may be attributed to sliding of sediments, because they occur on steep slopes.

C. ABSENCE OF AN ANNUAL RHYTHM IN THE DEPOSITS

Both planktonic life and especially the denudation of the islands in the Molucca's are strongly influenced by the alternation of the monsoons. The eastern half of the East Indian Archipelago, has a wet westerly monsoon and a dry easterly monsoon. In Timor and surroundings this climatic variation is most pronounced and the dry season generally passes without any rain at all. Thus in the rainy season torrential rivers carry down quantities of brown mud to the coasts, while in the dry season hardly any water flows out at the coast on these latter islands. A marked variation in the amount of materials carried out to sea in the course of each year must ensue.

I hoped, that this yearly rhythm would prove to be reflected in the sedimentation and that the samples would show an annual variation in colour and composition. With a rate of sedimentation of 10 cm per 1000 years, a rate that appears to be attained or even exceeded in many localities, the thickness deposited each year would be 0.1 mm. In a sample viewed through the microscope this stratification should be easily discernable. I therefore prepared several thin slices of undisturbed samples to examine by transmitted light and others to be viewed with reflected light. Some of these samples are shown on the Plates in Section II. In none could even the slightest indication of rhythmic stratification be observed.

The explanation of the total absence of sedimentary rhythms reflecting the monsoonal variations is not far to seek. Naturally a stratification of 0.1 mm or less cannot find expression in particles with a diameter of the same order of magnitude. Only when the grains are themselves considerably smaller than half the yearly deposit could the stratification show up. However, these small particles of clay, volcanic ash, etc. sink so slowly, that they take months or even many years to sink to the floor of a deep basin. Currents, turbulencies and convections will bring about perfect mixing on the way to the bottom. We need but refer the reader to the interesting conclusion arrived at by Miss Neeb, that the ash of volcanic eruptions may remain floating in the deep waters of the troughs for dozens of years on end.

The particles of dust and clay that are deposited on a small patch of the sea floor, will therefore not only have reached the sea at widely scattered places, but also at times separated by many years. All traces of a monsoonal variation in the rate of inwash into the seas, must be completely obliterated on the way to the bottom.

The general conclusion is, that an annual rhythm in the deposits of the East Indies is neither to be demonstrated nor to be expected.

D. RATE OF SEDIMENTATION

Prior to the investigations of the Snellius-Expedition absolutely nothing was known concerning the rate at which sediments accumulate in the deep basins of the Molucca's. Whether it took a year, a century, or even longer to deposit 1 mm was unknown. After Schott [1]) had established the order of magnitude for the tropical Atlantic, where he found 1.78 cm of blue mud, 1.2 cm of Globigerina ooze and 0.86 cm of red clay per 1000 years, the possibilities were also somewhat narrowed down for the Moluccan region. Obviously the sedimentation must be swifter here than far out from the coasts in the open ocean.

In the foregoing paragraph I showed that no yearly rhythm in the sedimentation occurs to give us a measuring rule. Neither did the long sampler succeed in reaching a buried stratum evidently belonging to the Ice Age. The Kaoe-bay must at that time have been converted to a freshwater lake

and it is certain, that the sampler did not reach the deposits of this period, although it penetrated to nearly 2 meters. But it is not unlikely that the quarternary sediments of the other basins also differ at least slightly from the recent deposits. One need only picture the conditions close to the Soenda and Sahoel shelves that were converted to dry land, to expect different deposits during the low levels of the sea. Yet the long samples of $1^1/_2$ m tot 2 m are uniform, apart from a slight darkening and consolidation downwards and occasional layers near volcanoes.

These facts render probable that the post-pleistocene sedimentation of the Moluccan basins has in general exceeded 2 m (see page 30) Taking the length of this period as 20.000 years, the conclusion is, that the rate of sedimentation probably exceeded 10 cm per 1000 years.

More definite figures were obtained by Miss Neeb when investigating the samples from the neighbourhood of some volcanoes. Both of the Tambora and the Oena Oena the products of the last major eruption, that occurred at known dates, could be detected in a number of samples. Sometimes it is only possible to show the minimum thickness of the stratum layed down after the eruption. There is moreover a very considerable variation in the amount deposited at the various stations. Nevertheless the average is based on a sufficient number of samples to give us very roughly the order of magnitude. Miss Neeb obtains a figure of 65 cm per 1000 years for the non-volcanic, terrigenous matter. As Schott's figure of 1.78 cm includes the non-terrigenous matter, Miss Neeb's figure is about 50 times as large.

This rate of sedimentation, that would result in 13 m post-glacial sedimentation, even without lime or volcanic matter, is unexpectedly high. One would wish for confirming evidence, especially as all samples used were obtained in the vicinity of larger islands where sedimentation is above the average.

A first check is found bij comparing the rate of sedimentation with the rate of denudation. Rutten calculated the yearly denudation for a number of Javanese rivers by multiplying the run-off with the content of silt and dissolved matter and dividing this amount by the drainage area of the river [1]). For mainly volcanic areas he obtained figures of about 0.5 mm per annum, while in the sedimentary areas about 2 mm per annum was deduced. As neither the annual rainfall, nor the topographic relief of the drained area appeared to have played an important part in determining the rate of denudation, Rutten's figures should also apply to the Moluccan region. As the sedimentary areas predominate over the volcanic and plutonic provinces I will take 1.5 mm per annum as basis. Dissolved matter, amounting to about 10 percent should be subtracted, but on the other hand the larger fragments rolled along the bottom are not included in Rutten's figures.

It is of more importance that the points at which the measurements on the Javanese rivers were carried out, are situated some way inland. A lower figure would have been found at the mouth, because part of the load has been dropped in the coastal planes. Although most of the islands in the Moluccas are steep right down to the coast, some of the rivers pass through swampy lowlands or even lakes. It will therefore be assumed that $^2/_3$ of the material is carried beyond the deltas; this corresponds to a yearly denudation of 0.9 mm.

A rough estimate shows that in the region covered by the expedition the land forms 18.4% of the sea area. Sedimentation from material washed into the sea should therefore attain 0.184×0.9 mm $= 0.17$ mm per annum in dry consolidated condition. To obtain the average for the whole area the contribution from corals, plankton and volcanic wind-born dust should be added.

The total area of land is somewhat over 700.000 km², hence the annual denudation is 0.6 km³. According to Sapper's tabulation [2]) the extrusion of ash by the volcanoes in the area under consideration between the years 1500 and 1914 has amounted to about 160 km³ or 0.4 km³ per annum. Most of this is derived from the Tambora eruption of 1815 (namely 150 kms) and this exceptionally violent catastrophe may result in an average that is too high. On the other hand little is known of the volcanic activity of the first centuries included in the calculation, resulting in too low an average. One might also use the amount delivered by all Pacific volcanoes, 314 km³, as a basis and take the same percentage of this volume as the Moluccan volcanoes form of the whole area, namely 70 against

[1]) L. Rutten: Over denudatiesnelheid op Java. Versl. Wis- en Natuurk. Afd. Kon. Akademie Wet. Amsterdam, Dl. XXVI, 1917, pp. 920—930.

[2]) K. Sapper: Vulkankunde, 1927.

340 volcanoes. This gives a somewhat lower figure, 63 km^3, or 0.15 per year. We will assume a yearly extrusion of 0.25 km^3.

The thickness of the ash layer at the foot of the volcano of Tambora directly after the eruption was 4 feet and on Bali (400 km away) one foot, so that practically all the material was thrown beyond the coasts of the island Soembawa. This will be the case in all larger eruptions and the smaller ones play a subordinate part. It will be assumed that $^4/_5$ falls in the sea in the area considered and that the solid amount would be $^2/_5$ of the given figures, that is 0.1 km^3.

As the denuded amount was estimated at 0.6 km^3 we must add $^1/_6$ to the amount denuded from the islands in order to obtain the total of inorganic sedimentation. The conclusion arrived at is that the yearly amount of solid sedimentation is $0.17 + 0.03 = 0.2$ mm.

This figure needs further correction. In the first place there must occur loss to the oceans. Although in our calculation a fair portion of the surrounding oceans was included, a scattering of the finest particles to greater distances will take place to supply part of the red clays and other non-organic deposits of the open oceans. A decrease of terrigenous sedimentation away from the coasts has been demonstrated by Böggild and Miss Neeb. Loss of material to great distances must therefore be limited. I will assume that $^1/_4$ of the material is carried outside the area in question. There remains 0.15 mm of solid sedimentation per year.

In the second place a certain amount must be added for coastal abrasion and for the contribution from organisms. The average lime percentage of all samples is 27, to which siliceous tests must be added, giving some 30%. Part of this lime is washed off the islands and is therefore already included in the calculation of the denudation, leaving about 20%. The average sedimentation then works out at $^5/_4 \times 0.15 = 0.19$ mm.

To calculate the thickness of the deposit the high percentage of water must be taken into account. By weight the water, as shown in chapter III, is on an average some 58%, therefore by volume some 75%. The yearly growth of the sediments on the floor of the basins is thus found to be of the order of 0.76 mm, or 76 cm per 1000 years. For the purely terrigenous material the figure obtained by this computation is some 50 cm per 1000 years. Miss Neeb's result from measurement was 65 cm. She believes this figure to be considerably above the average for the whole region, because the samples used were obtained at stations in the neighbourhood of larger islands.

In our calculation the average for lime works out at 20 cm per 1000 years. This amount must be somewhat too large as it is found from the arithmetical average of the samples. One should take into account that by this method the deposits accumulating at a slow rate such as the Globigerina oozes, are represented in too high a proportion. A figure of 15 cm per 1000 years for accumulation of lime will therefore be assumed. This figure is about 15 times that found by Schott for purely calcarous matter in the Atlantic. One might doubt whether a so much higher velocity is probable. But it should be noted that in our case much of the lime is detrital, not from planktonic sources. Moreover the average rate of accumulation for the lime fraction of the samples dated by the Tambora eruption is 13 cm per 1000 years, with a maximum of at least 45 cm (st 175), and these figures are in very good agreement with our calculation.

With lime there is always the complication to be reckoned with that $CaCO_3$ is subjected to solution. Only if the solution at the sites of these samples is about of average activity should a close correspondence of the figures be expected. Miss Neeb found only 1 cm per 1000 years, but this is based on one single measurement only and appertains to Globigerina ooze, a deposit that probably accumulates slower than fine detrital muds of $CaCO_3$.

Yet another more or less independent check of the results is possible. In our calculation the amount of terrigenous matter yearly denuded from the islands is supposed to be 0.6 km^3 and the volcanic ash was estimated at 0.1 km^3. Loss to the oceans, that is principally sustained by the fine clay fraction, reduces the former amount to 0.42 km^3. At my request Miss Neeb supplied figures for the areas occupied by the various types of deposit. From these the proportion of volcanic matter to terrigenous particles can be estimated at roughly 1 : 8. But as the relative rates of accumulation are not accurately known, the deduced proportion is only a rough estimate. As the estimate of volcanic sediment is on the conservative side, it appears probable that the estimate of terrigenous matter gained by this method is also on the low hand. Yet twice as much, terrigenous deposit as found above, namely $8 \times 0.1 = 0.8$ km^3 instead of our 0.42 km^3 per annum would follow from this method.

Finally a line of attack on our problem is as follows. The average percentage of lime in all depths is somewhat less than half that encountered by the Challenger or that Schott found in the Atlantic. As the terrigenous matter is thought to accumulate about 50 times as swiftly, the calcareous matter should be stored up some 20 times as quickly in the Moluccas. This figure is of the same order of magnitude as found independently above, namely 15 times.

The result of these calculations is found to be in very fair agreement with what Miss Neeb finds from measurement and they confirm her conclusion that the sedimentation of the Moluccan region is very much swifter than that in the open Atlantic. The chief uncertainty is how big the difference is between the basins close to the larger islands and those further away, for as I already pointed out Miss Neeb's figure applies to the former group while my result is an average of the whole region.

Finally there is a question of importance to stratigraphical geology, namely the number of years required to fill the deep-sea basins. Here we must take a much lower average water content, because compaction in a series of 5000 m thickness would drive out most of the connate waters. Assuming a yearly growth of 0.5 mm (average compaction taken into account) the time needed to fill the basins is of the order of 10.000.000 years. Obviously the volume of rock above sea level is very much smaller than the contents of the basins. Sedimentation could therefore only succeed in filling the troughs if the recent elevation of the islands noted on most coasts continues. There is reason to believe, that the floors of the basins have subsided comparatively recently and the powerfull negative isostatic anomaly points to the conclusion that subsidence may continue. In that case filling of the basins will of course take longer.

E. SLIDING OF SEDIMENTS ON SLOPING SEA FLOORS

An important question in relation to sedimentation and the structure of fossil sedimentary deposits is the degree and frequency in which freshly deposited matter tends to slip down slope. In part 2 of the Geological Results of the Snellius-Expedition, published in 1935, I already touched upon this subject (pp. 69 etc.). It was shown there, that normal, soft samples of blue muds, volcanic muds and Globigerina oozes were obtained on comparatively steep slopes. „Our data prove beyond doubt that the most mobile marine sediments known, can accumulate in thicknesses of upwards of 1 meter on angles of 15° in strongly seismic regions at all depths". Only in one case „hard bottom" was encountered on a slope (11°) where sliding may have caused the absence of sediment. But some other cause may be responsible, as it must have been in a similar find on a flat floor.

Stetson mentions the taking of samples on the slopes of submarine canyons off the east coast of North America. (Georges Bank) [1]). He says on page 343: „.... the gradient.... is considerably steeper than that of the continental slope" but gives no figures. This confirms my experience of recent sediments being found on considerable slopes.

Since 1935 further observations have been recorded of fossil sediments bearing the mark of submarine slumping (slip-bedding or syngenetic disturbances). Papers by Henderson and Klingner [2]) should be specially noted. Personally I was able to note several cases. One is in a core of carboniferous sandstone from the south of the Netherlands, where the sandy clay strata moved in layers of about 10 cm thick to form sharp anticlines. Another case is the dolomitic marl of the Muschelkalk beds in the eastern Netherlands. Here the strata are only 1 cm thick or less; they have formed breccia's, rolled balls, minute models of tectonic thrust structure, etc. I hope to treat this subject more fully in a separate paper.

From a review of literature on sediments the impression is gained, that although local slipping resulting in disturbed beds occurs now and then, it is a rare phenomenon. The number of cases in which the strata have remained undisturbed until lithified, are infinitely greater, even though we make allowance for frequent overlooking of signs of slumping. Evidently there was seldom sufficient

[1]) H. C. Stetson: Geology and palaeontology of the Georges Bank Canyons. Bull. Geol. Soc. Am. 1936, pp. 339—440.

[2]) S. M. K. Henderson: Ordovician submarine disturbances in the Girvan District. Trans. Rol. Soc. Edinburgh. Vol. LVIII, Part II, no. 20, 1935, pp. 487—509.

F. E. Klingner: Sediment-Rollen (Unterwassergleitung) im Muschelsandstein bei Saarlautern. Senckenbergiana, 21, 1939, pp. 311—314.

slope on the sea floor to cause slumping. This is in accordance with the dominant parallelism of strata when viewed over shorter distances.

In this type of sliding the distance of the movement is but small. Sediments that are sufficiently plastic to be folded and rolled up, cannot be firm enough to travel far down a slope. This is born out by the comparatively unintensive folding the strata generally appear to show.

When, however, the unconsolidated sedimentary stratum becomes entirely detached from its substratum and slips down a long or very steep slope, it will either break up and form an intraformational conglomerate or breccia [1]), or it will be changed to a mudflow. In the latter case it may be supposed frequently to become a watery avalanche: a density current. On reaching less steep slopes or flat sea floors such a density current will spread out over wide areas. The deposit resulting from a mud flow, especially of the watery type, may be expected to show little evidence of its eventful journey to the ultimate environment. It will be intercallated between the strata sedimented in situ, and escape special notice during later investigation of the lithified series.

The type of sliding first refered to, in which the distance travelled is quite small, would be difficult to detect in samples of recent deposits that show no stratification. The number of our samples, that are clearly stratified, is so small, that we could not expect to find so rare a phenomenon. On the other hand it appears doubtful whether such sliding could occur without the development of a clear stratification. As sharply defined layers without much change of material are not found amongst our samples, I am strongly inclined to assume, that the short-distance slipping is not respresented in any of the samples that could have shown the phenomenon.

In the second type of slumping the materials are redeposited at the lower end of the slope, possibly on quite different material. The scarcity of stratification in the Snellius samples also points to the infrequency of long distance sliding *in thin beds*, just as it ruled out local slipping. Whether larger masses flow down the steeper submarine slopes is a different question, for the resulting deposit at the foot of the slope would be too thick to render a stratified sample. It does not appear probable, however, that the deposit of a mudflow would so strongly resemble normal deep sea deposits as to escape notice. As a general rule the samples became gradually firmer and darker from the upper to the lower end. For the long ones taken with the Snellius-sampler there was no exception to this rule [2]). This would indicate greater age at the lower end and thus preclude deposition from a mudflow. Moreover, there was no upper layer resulting from the resumption of normal sedimentation in situ on top of a mudflow.

In discussing the lime percentage of the samples it is shown that a case, though not a very strong one, may be presented for sliding along steeper slopes. The reader is referred to the second section of this volume for Miss Neeb's findings on the subject of sliding. In part 2 of the Geological Results the provisional conclusion was drawn, that sliding of sediment in the Moluccan region in spite of its seismic nature, is a rare phenomenon and this conclusion is now arrived at again, although some slipping is now admitted on account of the mineralogical composition and of the lime percentage distribution.

F. OCEANOGRAPHICAL FACTORS GOVERNING SEDIMENTATION

1. Introductory remarks

Besides geological and biological aspects, sedimentation on the sea floor also presents problems of a physical and chemical nature. The sinking of particles and the distribution over wide areas are principally influenced by currents, waves, turbulence, etc. The solution of lime and the deposition of manganese are chemical problems. In the examination of bottom samples the investigator is therefore forced to formulate a number of questions, that should be answered by oceanographers. Unfortunately up to date the physical and chemical measurements of the Snellius-Expedition have not been worked out in most of the respects in which our problems demand oceanographical data.

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[1]) E. B. Bailey and J. Weir: Submarine faulting in Kimmeridgian times: East Sutherland. Trans. Rol. Soc. Edinburgh, Vol. LVII, Part II, no. 14, 1932, pp. 429—467.
E. B. Bailey, L. W. Collet and R. M. Field: Palaeozoic submarine landslips near Quebec City. Journ. of Geology, Vol. XXVI, 1928 pp. 577—614. W. H. Twenhofel, Treatise on sedimentation, 1932, pp. 102—103.

[2]) For the normal samples I cannot be quite sure, as no special note was made of these properties during the expedition.

To await these before bringing the present volume to a close would not only be impracticable, but it is even doubtful whether a satisfactory answer to our questions will ever be found from the available measurements. We are therefore forced to leave several points open, that may in the long run find a solution in the oceanographical deductions.

Yet there are some questions of such importance that a provisional answering must be attempted or at least attention must be drawn to them. I wish to thank the oceanographers of the expedition for valuable advise and aid in arriving at the following preliminary estimations and speculations, while Professor J. M. Burgers of Delft also kindly helped me.

2. Currents retarding the sinking of particles

A very interesting problem arises from Miss Neeb's findings concerning the rate of depostion of ash particles from volcanic eruptions, especially that of the Tambora. Miss Neeb points out that the ash of the Tambora eruption of 1815 is still accumulating on the floor of the Flores basin. This means that during the 120 years that have elapsed since the ash was thrown into the basin, all grains have not yet succeeded in reaching the bottom. Although the particles dropping on the floor have become continually finer, most of those settling at the time of the expedition were so large (5μ and more) that they should have reached the bottom in less than 4 years. Miss Neeb suggested that this retardation should be attributed to turbulence due to the currents in the basins. In reviewing this phenomenon we soon found that the oceanographical problems must be complicated. The following is a provisional attempt at discussing the oceanographical aspects on the meagre data at hand, in the hope of stimulating a deeper inquiry by a specialist.

The microscopic examination of the bottom samples shows, that the Tambora ash is deposited together with terrestrial clay. Subtracting the ash, the clay is found to form a layer 2—15 cm thick in the upper end of several samples. As the clay is sedimented slowly and as nevertheless many centimeters of this material have been deposited since the eruption, it is established beyond reasonable doubt that the upper part of the sample was deposited in the course of the years since 1815 and the top was formed just before the expedition arrived. If only ash were found, one might suppose that the whole length had been formed soon after the eruption and without further sedimentation since then. Now, however, we are forced to assume that Tambora ash was still dropping to the sea floor 120 years after the eruption.

The obvious suggestion that this ash is up to the present day being swept off the island of Soembawa, where the Tambora lies, by streams, has also been ruled out by Miss Neeb. The material shows no signs of subaerial weathering and consequently it cannot have lain long on dry land. Further more it has become increasingly finer during the intervening 120 years, but there is no reason why ash brought down to sea by streams should have become finer and finer in the course of time. Finally ash of other volcanoes such as those of eastern Java, that is carried to sea by streams, and is known to be readily recognisable, was not found by Miss Neeb in the samples taken at short distances from Java. Similarly the denudation products of Soembawa should not be met with in the deepsea deposits.

We just learned that the size of the ash particles sinking to the floor at the present moment is such that they would sink all the way in undisturbed water in a few years at the most.

To keep the particles from reaching the bottom a current with a vertical component of some 2000 m a year is called for. Several possibilities present themselves: 1. a renewal of the water in the basin without stirring; 2. a renewal by turbulent currents; 3. a slow renewal of the homothermal waters combined with vigorous stirring by convection or turbulence due to other causes. Let us examine these pictures separately.

1. The first supposition is that the waters in the basin are heated by the internal warmth of the earth and while rising suck in new cold waters over the threshold. Arrived at the level of the threshold the warmed waters flow out horizontally again (fig. 6 A). If the gradual rise of the waters in the basin is to keep the ash suspended, it must attain to a velocity of a couple of kilometers per year. As shown in a later paragraph, the ventilation is some 100 times slower, so that this picture as a possible explanation must be discarded.

2. If the incoming current is supposed to be of great vertical thickness, the general direction of the movement would be horizontal, not vertical (fig. 6 B). But if this current were turbulent the vertical component might be responsible for keeping the ash afloat. In that case it is evident, however,

that the vertical velocity of the turbulent currents must be at least as large as the sedimentation velocity of the particles. J. M. Burgers tells me in private correspondence that he would expect the turbulent velocity in a current through the basins to be of the order of 10% of the velocity of the current itself. We would need a current with a velocity of 20 km per year (0.6 mm/sec). As the deep part of the Flores basin is about 500 km long, the basin would be ventilated in 25 years by such a current. And where towards the end of the basin the current becomes slower and the turbulence dies out, the ash would not be kept in suspension, but allowed to drop to the bottom. In the available 120 years since the eruption one would expect practically all ash to have been deposited or carried away. Moreover, as shown below, the available data point to a considerably slower rate of ventilation [1]).

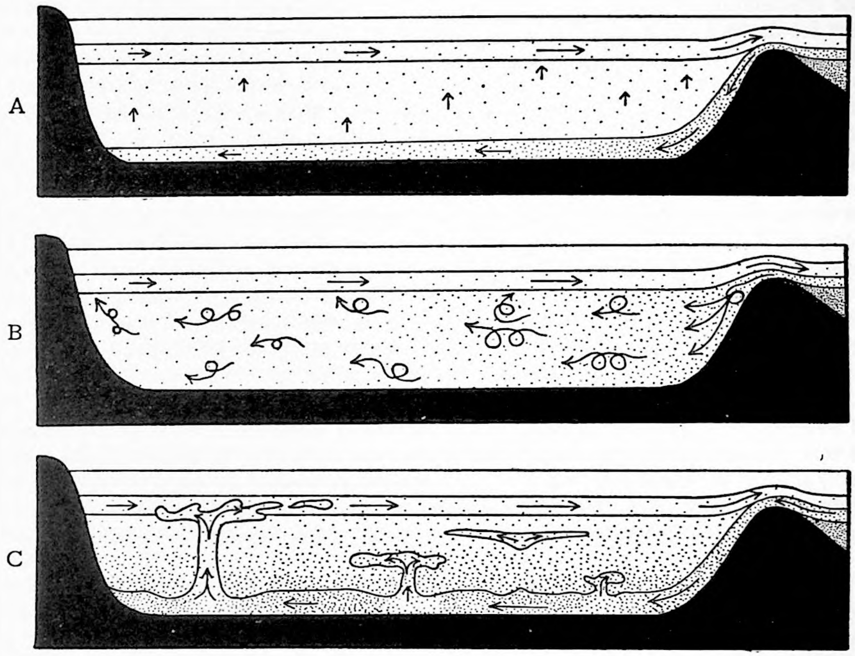

Fig. 6. Various possible types of stirring in deep sea basins.

But, as Hamaker suggested in private correspondence, turbulence due to some other cause may be superimposed on these gradual ventilation currents. The flow of heat from the earth, monsoon — or tidal currents may possibly stir the homothermal deep so vigorously, that the particles of ash are kept from sinking.

The monsoon winds must carry the waters at the surface along, and compensating currents will flow back deeper down. But the stable stratification of the waters due to differences in temperature precludes that this latter current should continue in the cold, deeper strata and the homothermal deep for any length of time.

A next line of thought is that the internal heat of the earth may result in active stirring. Molengraaff [2]) was the first to point out that the flow of heat from the earth must result in ventilating the deep basins of the East Indies, thus giving the waters power to dissolve lime continuously. The slow inflow of cold water takes place over the threshold and sweeps down along the inner slope to the floor, spreading out and gradually slowing down as it goes. An amount of water, equal to the inflow and of slightly higher temperature, CO_2 and lime – content and lower oxygen, is carried out of the basin in a current passing over the intake-current.

[1]) We will return to the effect of turbulence on suspended matter below.
[2]) De zeeën van Nederlandsch Oost-Indië, 1922.

If the cold inflow spreads out below the homothermal waters of the basin continuously without thermal convection as supposed under 1, it would be heated and a gradual rise of the water of almost equal potential temperature would be found (complete mixing in the intake by the swift reversing tidal currents over the threshold with vigorous eddies and turbulence may be assumed). As, however, there is a gradual increase of potential temperature from the basin floor upwards, there must take place a transportation of heat from below quicker than the average rise of the waters, or conduction from above.

For judging whether true conduction from above may account for this heat transport the actual, not the potential temperatures must be consulted. The oceanographical sections show that there is a level of minimum temperature at the top of the deep, somewhat below the threshold. Further down the temperature in situ rises in consequence of the adiabatic compression. The necessary conditions for the true conduction of heat downwards in the deeps is therefore lacking.

On the contrary conduction must carry heat upwards. But the temperature gradient is exceedingly low, attaining but a fraction of a degree per 1000 m. In order to carry the heat of the earth away, 50 cal. per cm^2 per year, a temperature gradient of 150° C per 1000 m is requisite. Evidently true conduction is of no influence in the distribution of temperature.

The only other possibility of heat transport is by *convection*, due either to internal heat or to stirring by tidal currents.

Let us examine first the hypothesis of thermal convection in consequence of the flow of heat from the earth. This view that the warmth comes from below would present few difficulties, if the deeps were strictly homothermal. But, the data show a distinct decrease of potential temperature even in the part that is roughly homothermal. Thus van Riel's section fig. 8 (Vol. II, Part 2, Chapter II) shows the potential temperature (that is the temperature in situ minus the rise in consequence of adiabatic compression) at the bottom of the Celebes sea to be 3.26° and in the level of minimum temperature in situ at 2475 m (see his table on page 56) to be 3.36°, that is 0.1° C higher. Similar conditions are met with elsewhere. This decrease can be followed step by step in the hundredth parts of a degree right down to the floor. As there is not a warm stratum on the bottom, we must suppose that in a general way the water heated by the earth rises upwards before being warmed as much as $^1/_{100}$°. On the other hand some of the water must attain $^1/_{10}$° higher temperature before flowing upwards, otherwise there could not be the difference between floor and upper part of the homothermal deep. Possibly the warmer uprising waters are to be sought further away from the inflow.

It could be suggested, to account for the gradual rise of temperature from the floor upwards, that some convective overturns start on a rise of temperature of considerably less than $^1/_{10}$° C. These flows cannot rise more than a few hundred meters. Others become more strongly heated, up to a maximum of $^1/_{10}$°. The latter go eddying right up to the top level of the homothermal deep. Here the water mixes with the outgoing current and is in course of time carried away out of the basin (see fig. 6, C).

There is thus supposed to be intermittant convection, with currents rising to different levels and starting now here, then there. There need be no localised downward movement, but only a slight general sinking of the whole homothermal mass to take the place of the rising water. On these movements, that about counteract eachother, is superposed a slight upward movement of the whole mass in consequence of the new water coming in along the bottom.

In the following paragraph it will be shown that calculations of the rate of ventilation based on this picture, tally satisfactorily with figures arrived at by an independent method. This gives some support to the general principle of convection outlined above, but there is also another possibility to be discussed now.

Current measurements on the anchoring stations have shown the occurrence of strong tidal currents even at great depths. These currents are so swift as to be certainly accompanied by turbulence. This stirring action may account for the suspension of the ash, but absence of data renders a direct caculation impossible. I strongly incline towards supposing that the heat of the earth and tidal currents combine to stir the waters in the homothermal deeps. Before entering into a discussion of indirect methods of estimating the strength of this stirring we must first treat the problem of suspension by eddying currents in connection with the floating Tambora ash of 1815.

The coarser material will sink so swiftly that it reaches the bottom in a few days or weeks and is not noticeably retarded by any type of turbulence in the deep. As soon as we consider the finer fragments, that need many weeks or even months to sink through a water column of 5000 m, the matter lies differently. The current measurements of station 317a on the threshold of the Flores sea to the Banda basin show that down to the bottom at 2000 m depth an average current of some 6 cm/sec (= 5 km/day) is directed towards the east. In the wider basin the current must be slower and more varying in direction; let us assume $2^1/_2$ km per day. To carry a chip of ash from the Tambora out of the basin eastwards would take half a year. Most of the material was dropped to the west and some to the east of the volcano. As most of the particles of ash will have sunk below the lowest level of the easterly currents in less than half a year, only a comparatively small percentage will have been born directly out of the Flores basin.

The bulk of the ash of 1815 reached the quiet waters of the homothermal deep and we must now consider separately what happens here. Unhappily there are no direct indications of either the volume or the velocity of convective currents. If they are slower than the sinking rate of the ash particles, these will all fall to the bottom within a few years. There is, however, no objection to supposing the vertical currents to be several times swifter than the sinking rate of the smallest ash particles. The convection currents could then also carry somewhat larger fragments back to the top of the basin and appreciably retard even the medium sized ones.

It should be noted, however, that when the material is distributed homogeneously, turbulence will not influence the average rate of sinking. For the amount of sediment carried upwards at one point will be exactly compensated by an equal amount carried downwards at another spot. In order that sedimentation be retarded a concentration increasing towards the bottom is required. In that case the upward currents will on the average contain a greater amount of matter than the downward ones and their combined effect is a transportation of matter in an upward direction, which may partly or even wholly counterbalance the sedimentation. The influence of turbulence may be considered as a type of diffusion.

In the mathematical treatment of turbulence the whole body of water is divided into equal portions and the interchange in position is supposed of these equal parts in pairs and they are then thought to mix with their new surroundings. The same result may be obtained by moving the interchanging volumes slowly over a large distance or swiftly over a short distance also by assuming a strong fall in concentration and a slow turbulence or a small difference in concentration and a vigorous turbulence.

In order to obtain an upward diffusion of the ash particles that compensates the rate of sinking, so as to keep them afloat, Burgers assumed tentatively a concentration in the lower reaches of the homothermal deep of 150 times that at the top. The coëfficient of diffusion then workes out at 2×10^3 C.G.S. This amount is found to be more than the value deduced from observations at the surface of the sea during severe storms [1]). So strong a stirring in the deep basin seems highly improbable. Moreover, Hamaker calculated that the consequent conduction of heat downwards would be of the order of 30.000 cal. per cm² per year with the observed temperature gradient in the basins. The homothermal waters would then be some 10° warmer than they are actually found to be. Finally Seiwell and others found the turbulence in 600 m depth in the Caribbean sea to be only $^1/_{1000}$ of this amount, namely 2.8 C.G.S. [2]). If one were to assume a turbulence only 10 times that calculated by Seiwell, the downward conduction of heat would not raise the temperature of the waters more than appears compatible with the oceanographical data at hand. On the other hand an impossibly large difference in concentration of the ash between the top and the bottom of the homothermal deep must be assumed to compensate the sinking. Even with a coefficient of turbulence that is only 10 times smaller than that assumed by Burgers the difference in concentration would be of the order of 10^{11}. This would mean that practically all ash was concentrated at the bottom of the column, there forming a thick suspension.

As the vertical movements must die out in the bottom layer of water where it is in contact with the sea floor, there is always a zone with decreasing power to keep the particles afloat just over the

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[1]) A. Defant, Dynamische Ozeanographie, 1929, p. 76.

[2]) H. R. Seiwell, Eddy Diffusion at Mid-Depths in the Caribbean Sea Region. Journ. d. Con. Perm. Int. Expl. d. l. Mer. Vol. XIII, no. 2, 1938, pp. 155—161.

bottom. Part of the ash is continually brought into this layer from above and it then drops to the bottom. The greater the concentration of particles in the lower reaches of the homothermal deep, the stronger this action will be. Assuming an even distribution throughout the whole depth of the basin Hamaker calculates that in t years' time the total amount of ash in the deep would have been reduced by a factor $e^{-(v/H)\,t}$ where v = the distance travelled by a particle in one year and H = the height of the homothermal deep. For instance for $v = 1000$ m, $H = 2500$ m and $t = 120$ years the concentration will be $e^{-48} = \pm 10^{-21}$ times smaller than at the outset. As there would be a concentration of ash towards the lower end this loss would be even swifter. In other words: even if turbulence were able to keep the ash from sinking, loss at the sea floor would still be so large that in a few years time no particles would remain in suspension.

A final great difficulty in supposing turbulence to be responsible for the observed retardation in the sedimentation of the Tambora ash, is that the particles of clay that are being laid down together with the ash are much smaller. For flakes of clay ten times smaller than the chips of ash a concentration a hundred times greater is requisite for an equal amount of sedimentation. And as at present more clay is being deposited than ash, a very much greater concentration of clay in the water would have to be assumed. Yet no trace of visible turbidity was ever detected in our water samples.

Although we have not succeeded in solving the problem of the floating Tambora ash the hypothesis of convection by internal heat and tidal currents appears to account satisfactorily for the further observed facts, viz. 1, that the cold water flows in over the threshold and may be followed as a shallow streak along the inner slope into the basin; 2. that the sea floor is found to be swept clean of fine deposits a considerable way down this slope (see station 297 at 2700 m inside strait Biaro in the north-eastern inlet of the Celebes sea, that is 1300 m deeper than the threshold); 3. that there is a gradual rise of potential temperature from the bottom to the top of the homothermal basins, a rise that is several hundredths of a degree, but that can be followed regularly in the readings of the thermometers with an accuracy of one hundredth of a degree; 4. that the homothermal deeps are ventilated (dissolved gases and lime).

Summarising the results, of this provisional enquiry into the possibilities of retarding the sedimentation of the Tambora ash of 1815 by some type of current in the Flores sea, we are forced to admit that no adequate current or turbulent flow appears to occur and that even if the eddying movements were sufficient at some distance above the sea floor to keep the ash from sinking, a few years would yet see all particles dropped to the bottom.

Evidently the problem cannot be solved on the available data, for the arguments put forward by Miss Neeb are no less pertinent than the oceanographical deductions just set forth. In the first place currents measurements in the centre of the Flores sea are required and other oceanographical data concerning the circulation in the deeps. Further, water samples should be centrifuged to find the amount and nature of suspended matter at various depths. The distribution of the Tambora ash on the sea floor, especially along the length of a number of samples should be ascertained. The condition of the Tambora ash on the island Soembawa should be studied and the river waters analysed on the possible presence of floating particles.

3. Renewal of the water in the deep basins.

If the picture of the convective currents caused by the heat of the earth, as deduced in the former paragraph, were correct and no conduction by turbulence from above occurs, a rough estimate for the rate at which the basins are ventilated may be calculated from the rise in temperature. Although the uprising of water occurs irregularly (fig. 6, C), the difference in temperature between the bottom water and the upper level must represent the amount of heating a column of water, as long as the depth of the homothermal part, will undergo during its sojourn in the basin. This conception is based on the fact that all the water entering the deep is of the temperature found on the floor and all the water going out is $^1/_{10}$° C warmer, as shown above. The same result would be attained if the entire basin were suddenly charged with cold water and left to be heated $^1/_{10}$° throughout and then recharged anew. The chief obstacle to arriving at an accurate estimate of the time required for such a heating cycle, is that we do not know exactly to what temperature the water is heated. It has not yet been accurately ascertained at what level occurs the ventilating current, carrying the old water out of the deep. At the upper level of the homothermal deep mixing with the warmer waters from

above takes place and therefore the potential temperature in the level of minimum temperature is probably somewhat higher than would result from the internal heat of the earth alone. We must therefore expect to find a period that is on the long side. On the other hand the possibility must be admitted that the waters coming up out of the deep reach a slightly higher level than that of minimum temperature in situ, in which case the earth would need a longer period for the heating.

Now the flow of heat from the earth is about 50 cal. per square centimeter per year and the depth of the homothermal basin of the Celebes sea is 5000 — 2475 = 2500 m. To heat this column of water $^1/_{10}$° C would require about 500 years.

As pointed out in the former paragraph the stirring caused by tidal currents must also cause a transport of heat, in this case downwards. The larger this influence the greater the amount of cold, incoming water that can be heated so as to pass out of the homothermal deep. If the influence were ten times that of the heat of the earth, the deep would be filled with water almost 1°C higher than the average of the incoming current. As far as can be judged from the depths of the thresholds and temperature of the deeps the turbulent conduction of heat cannot much exceed the influence of the internal heat and I am inclined to believe it is hardly as great. The ventilation of the deeps would then occupy some 200—300 years.

This figure may be checked by an entirely independent method for calculating the period of ventilation. Current measurements were carried out in several straits and from these the rate of renewal in the deeps is deducible.

At present an estimate can only be made for the straits between the Soela-island Lifomatola and Obimajor. Here we have both an oceanographical section by v. Riel (Vol. II, Part 2, Chapter II, fig. 14) and current measurements (Lek: Vol. II, Part 3, pp 62—87) at our disposal.

The current passing through this narrow entrance supplies the Boeroe basin, the whole Banda basin, the Flores basin, the Weber deep, Sawoe basin and the Gulf of Boni with deep water (v. Riel l.c., Plate IV). The thickness of the current passing southward may be estimated at 400 m (1400—1800 m) (v. Riel's section). The varying current has a southward component with an average velocity of 5 cm/sec in 1500 m depth. The average of the whole current may be put at 7 km/day. The cross-section of the current is about 6 km^2 so that the daily intake into the basins is 42 km^3.

The combined surface of the basins is roughly 900.000 km^2 and the depth in the homothermal mass some 2 km. We thus find a complete renewal of the homothermal waters in 43.000 days or 120 years. Hamaker points out, however, in personal correspondence that the inaccuracy of the current measurements may be considerable owing to various reasons. The sheering of the vessel on the long anchoring cable will tend to pull the measuring apparatus through the water. If the apparatus does not sink down absolutely vertically on being paid out, it will swing back to its point of equilibrium during the measurement. The calculated current is consequently in all probability too high and therefore the period of renewal based on it too short. It appears safe to conclude, that the ventilation requires between one and a few centuries.

Some confirmation is given by the less complete data for the Celebes sea with the Makassar straits. Here we have no current measurements, but the oceanographical section (v. Riel, fig. 8) indicates a thinner current of some 250 m depth. The length of the section is about equal to that in strait Lifomatola, but it is divided into three separate parts. The area of the section being less, the run-off would appear to be smaller for the current into the Celebes sea. But the area served is also smaller, — about half — so that the ventilation period should again be of the same order of magnitude.

For calculating the currents in the passage between the Flores sea and the Banda sea the data are insufficient. From v. Riel's figure 20 and the detail chart 8, the cross-section is found to be about 10 km^2. This is larger than of the current in the Lifomatola strait, used above, supplying the 20 times larger basins of which the Flores sea is but one. The oceanographical section gives the impression of a much more leasurely current, as is to be expected. On the other hand the current measurement in 2000 m, that is at the very upper edge of the ventilating current, is half that of the flow in the Lifomatola strait. The bulk of this measured current is probably due to the inaccuracies noted above.

The two figures arrived at for the period of an entire renewal of the homothermal deeps, may now be compared. From the current measurements a period both for the Banda basins and the Celebes sea was found of between one and a few centuries. The heating of the waters in the Celebes sea

points to a sojourn in the deep that is in all probability less than 500 years. These two figures, although arrived at from entirely independent data and by entirely unrelated methods, could hardly have been hoped to accord better. Some 200 or 300 years appears to be a fair estimate of the period required.

4. THE SOLUTION OF LIME IN THE BASINS

The next point is to ascertain how much lime could be dissolved by the water, now that the rate of ventilation is roughly established. At present we cannot say much, because nothing has yet been published on the chemical composition of the water samples taken. In future it may even be possible to check the amount dissolved by comparison of the calcium percentage and volume of the intake with those of the waters passing out of the homothermal basins. Up to date all we can do is to estimate whether the solution of lime is limited by the solvent capacity of the water, by inability of the water to reach the calcareous tests, or by the inadequate amount of calcareous tests sinking into the basins. As there are large areas with lime-rich deposits, the latter possibility is directly ruled out.

In a former section the rate of accumulation of lime was estimated at some 15 cm per 1000 years. This would contain roughly 10 grams of solid $CaCO_3$ per cm^2. If the renewal of the water in the homothermal part of the deep basins takes 250 years, there are 100.000 parts of water to every part of lime.

Even if twice as much lime is dropped into the basin as ultimately accumulates on the floor, then there would still be 50.000 parts of water to every part of lime to be dissolved. The total amount of lime that can be dissolved in Atlantic waters at 2000 m depth is about 1 in 10.000 according to the results of the Meteor-Expedition.

The above calculation shows that it may safely be assumed, that all lime particles sinking into the homothermal basins could be dissolved if the water were to become fully saturated, taking into account the increase of CO_2-pressure by animal life during the stay of the water in the basin. In other words: the fact that lime is deposited must be attributed to insufficient contact between water and lime particles, not to lack of ventilation of the water in the basins. The water passing out of the deep should be undersaturated with lime.

Limited contact between the lime particles and the water may be brought about by several causes, and various views have been put forward on this subject. When, after death, the Globigerina test sinks to the bottom it may pass through the water too quickly to be dissolved. This is probably the case in general, because organic matter (keratine) protects the lime (Correns in: Barth, Correns, Eskola: Die Entstehung der Gesteine 1939, p. 198). Moreover, Globigerina ooze accumulates at dephts of 4 to 5000 m in the oceans, where the tests have sunk all the way through water undersaturated with lime. This indicates only limited solution during sinking in deep water.

But even the particles of detrital lime, that are washed out to sea by rivers, or dashed from the coasts by waves, reach the bottom in large quantities, although they are not protected by a film of organic matter. Most of the lime in the East Indian oozes is of terrigenous origin.

A further check put to the solution of the lime particles, when they have once reached the bottom, is the limited mixing of the deeper strata of water and consequent approach to saturation. Wattenberg was able to show that close to the bottom the alcalinity of the water rises considerably, owing to the solution of lime. This proves in the first place, that all solution does not take place during sinking, but that it continues after deposition. In the second place it shows, that this latter solution is retarded by insufficient mixing of the bottom layer of water.

In the absence of chemical data one might suppose the same conditions to prevail in the East-Indian troughs as in the tropical Atlantic. But probably the circumstances are somewhat different. Molengraaff (l.c.) already drew attention to the internal heat of the earth as a potent factor for furthering the solution of lime by causing convection in the basins. In the preceding paragraph we were able to add a certain amount of precision to these ideas.

The temperature measurements appear actually to indicate that thermal convection is active, and that the bottom layer of water is slowly but continually renewed. This forces us to assume, that the calcareous tests are protected from solution, partly by the organic film and partly by covering with clay and other tests.

Is the rate of accumulation sufficient for covering the shells? If the sedimentation attains onlv

2 cm per 1000 years, the larger Globigerina tests are entirely covered in some 25 years. But a film of clay that must greatly retard the solution will have formed in a few years. If the accumulation is considerably swifter, as appears probable for the East Indies, the smaller planktonic Foraminifera will be entirely buried in a few years or even months and effectively protected by clay in several months or even weeks.

We can now attempt to make a very rough estimate for foraminiferal tests of the relative importance of dissolving during sinking and the solution taking place on the sea floor. The planktonic Foraminifera vary greatly in size and shape. For some samples the size 0.5—0.2 mm predominates, for others smaller fractions. In view of the rough and hollow shape we may assume the larger specimens to sink in cold seawater at the rate of a quartz sphere of 0.1 mm in fresh water = 8 mm/sec. Such a test will sink to a bottom of 5000 m in a week. Particles 10 times smaller will sink at 0.15 mm/sec and therefore need $1^1/_2$ years to reach the bottom. In both cases the test drops through 5000 m of water. From the calculated rate of renewal of the basin content it follows that the average current has a velocity of about 10.000 m per year or 30 m per day. Along the bottom the current is slower, but thermal convection will somewhat counteract friction. Let us assume a velocity of 5 m per day.

We thus arrive at the following conclusion. A particle dropping to the bottom passes through 5 km of water. Laying on the bottom it is washed for instance during a month by 150 m only before being buried; much less solution taking place on the sea floor. But where the bottom current is swifter the accumulation and deposition of protecting sediment will be slower and the rinsing will be more effective. Under these conditions more solution could take place after deposition than during settling.

In spite of the many uncertain factors the above estimations have taught us at least something, namely that solution both during the sinking and after deposition may play an important part. The relative importance depends on several uncertain, oceanographical factors and on the size of the particles in question and the durability of the keratine substance.

5. Scattering of particles by horizontal currents

Although a geologist would wish for fuller data than have been brought together by the Snellius-Expedition, the results published by Lek in Vol. II, Part 3 of the reports are sufficient to gain a general impression of obtaining circumstances. Our chief desideratum for future investigations would be for regional information; that is for maps of all basins giving a three-dimensional picture of the direction and velocity of water transport. Even a few figures for the central parts of the major seas would greatly increase our knowledge, for Lek's data appertain almost solely to stations situated in narrow and shallow entrances to the basins.

The following general conclusions appear warranted. Down to a depth of 1000 m the constant currents are of the order of 15 cm per second. Below that level an average of 5 cm per second was measured. (Tidal effects are not included in these figures as they do not result in a permanent displacement of floating particles). As the direction of the currents varies considerably for different depths and the measured values are apt to be on the high side (see paragraph 2), the net result on a sinking particle will be somewhat less, about 10 cm per second for the first 1000 m. Taking the average sinking velocity of particles to be half that of quartz spheres in fresh water of 15° C the time needed to sink 1000 m and the consequent transportation are as follows [1]).

diameter	velocity	per 1000 m	transported	
			0—1000 m	1000—5000 m
1 mm	50 mm/sec	6 hours	2 km	4
0.1 mm	4 mm/sec	2 days	25 km	50 km
0.01 mm	0.07 mm/sec	6 months	1500 km	3000 km
1 μ	0.0007 mm/sec	40 years	150.000 km	300.000 km

[1]) Deduced from values given by Twenhofel: Treatise on Sedimentation, second edition, 1932, p. 52.

These rough figures show that particles of more than 0.1 mm such as larger planktonic Foraminifera drop to the bottom almost where they die or where they are introduced into the sea. Smaller planktonic shells may drift across a basin while sinking, especially if the spikey form causes slow sinking. Fine volcanic ash of 5 μ diameter may be carried from one basin into the next or even right across the Moluccan region before reaching the homothermal deeps. As for flakes of clay of 1 μ and less there is no limit to the distance of transport, for they could be carried three times round the earth while dropping the first 1000 m. It is of the greatest importance when considering problems of sedimentation in these parts, to bear in mind the great distance, smaller fragments may travel on their way to the bottom. The complications introduced by vertical currents have been dwelt on in a former paragraph.

Little need be said here on the strong, especially the tidal-, currents sweeping the thresholds between basins. On the map of the bottom deposits in Section II the sites have been marked where hard bottom was sounded and in the list of samples the stations may be found where abnormally coarse sediment was encountered.

SUMMARY AND SUGGESTIONS FOR FUTURE INVESTIGATIONS

The first two chapters of this report deal with the apparatus and methods of sounding applied during the Snellius-Expedition. These pages are mainly of interest for those planning future investigations. Below will also be found a few suggestions for future sampling and problems that could be tackled during an investigation of the Moluccan region.

Chapter III begins with a treatment of the data on organic content supplied by Parker D. Trask. It is shown that there is a correlation between lime and organic content, between clay and organic content and also between depth and organic content. The relations between organic content and distance to the coast are less clear. The strong increase in organic content with the clay fraction is most striking. This must be the reason for the high organic content of the shelf sediments, where these contain a large fraction of clay. Otherwise such shallow deposits should be almost free of organic matter. No relation was found between the organic content and the amount of oxygen in the overlying water.

Six bulk analyses by Miss Koomans show fairly normal compositions, but the Na-percentage is high.

The lime content of the individual samples is treated by Miss Neeb in Section II of this report. Here some statistical aspects are viewed.

Radium analyses by R. D. Evans of a few samples gave characteristic, high figures. The high rate of sedimentation in these parts has not resulted in diluting the radioactivity. Evidently it is a property of the particles themselves, not of an independently deposited product. There is no close correlation either with depth or with the clay fraction of the samples.

In Chapter IV a number of disconnected problems are dealt with in turn. The anaerobic conditions in the deep of the Kaoe bay have resulted in the deposition of mud containing H_2S. The colour, however, is green, although elsewhere black mud accumulates in water containing hydrogen sulphide.

The absence of any stratification caused by the Ice Age may be due to the great thickness of post-glacial deposits. The scarcity of layers and the absence of annual rhythm is readily explained by the great depth of the basins. The sinking of particles takes so long, that scattering over enormous areas and over great lengths of time must take place before materials, newly brought into the surface waters, reach the bottom.

A calculation of the rate of sedimentation, based on the probable denudation and volcanic production results in a figure of 75 cm per 1000 years. The terrigenous matter accumulates at 50 cm per 1000 years. This amount is in close agreement with what miss Neeb measured as having accumulated since the Tambora eruption on 1815. At this rate the basins would be filled in some 10 million years, assuming continuous supply of detritus.

Reviewing evidence on sliding or slumping of sediments the conclusion is arrived at, that this phenomenon is of little importance in these basins, although it may occur occasionally.

Some provisional conclusions are offered on oceanographical factors governing sedimentation, while awaiting the discussion of these matters by oceanographers. First the problem is attacked of hypothetical turbulent currents that have obstructed the settling of the Tambora ash of the 1815 eruption. The result is negative in so far that no adequate reason can be found for more than a slight retardation of settling. Turbulence cannot keep particles of ash afloat for indefinite periods, while at the same time allowing clay to settle out.

An attempt is further made to estimate the time needed for renewal of the waters in the homothermal deeps. Two methods are used that give comparable results in the order of one or a few cen-

turies. This figure is used to show that the solution of sinking calcareous tests is not restricted to the period of sinking, but continues on the bottom: there is an excess of fresh solvent water over lime, and the limitation of solution is due to the protection by keratine and embedding insoluble materials on the sea floor.

Problems for future investigations, both directly relating to sedimentation and those of an oceanographical character, are many and partly so obvious as to need no further comment. The regional distribution of the various types of deposit should be more precisely ascertained by extensive sampling. The relation between currents, river mouths, coral reefs, volcanoes and other factors influencing the distribution of material forms a large field of inquiry. The growth-rate of planktonic Foraminifera and other organisms met with in the samples is still entirely unknown. The composition, especially with relation to CaO, of the waters entering and leaving the homothermal deeps could help to elucidate the problem of lime solution. More facts should be ascertained concerning the movements of the water in and through the deeps, before a satisfactory answer could be ventured to the question how sinking particles are retarded on their passage to the deep floors of the throughs and basins. Investigations on land and centrifuging of water should also be undertaken in this connection.

The water content of a number of long samples should be carefully determined as soon as possible after the sounding. This would show whether there is a gradual and persistent decrease downwards due to compaction. In combination with determinations of the Na_2O content of the upper and lower ends of the same sample this would shed light on the problem of the high salinity of connate waters in oil pools. This question is also of great importance for calculating the total amount of sediments formed during the history of the earth, a question dealt with by the present author in an article that appeared in the American Journal of Science in 1941.

The sampling in shallow waters has so far been neglected although fossil sediments are practically all from shallow environments. The study of ancient sediments therefore calls for data especially on recent deposits from the coast out to the 200 m-line. Amongst others the organic content of such samples should be ascertained, while radioactive analyses are likewise needed.

In the introductory chapter it was already pointed out that there is no lack of interesting and significant problems in connection with the sediments of the Moluccan region. This short summary will help to bear out that statement, and Miss Neeb's contribution brings forward other unsolved problems worthy of investigation.

GEOLOGICAL INSTITUTE
Groningen.
VIII 1942.

Fig. 1. Dr. Hardon at the Lucas sounding machine

Fig. 2. Ekman bottom sampler.

Fig. 3. Monaco sampler with additional weight.

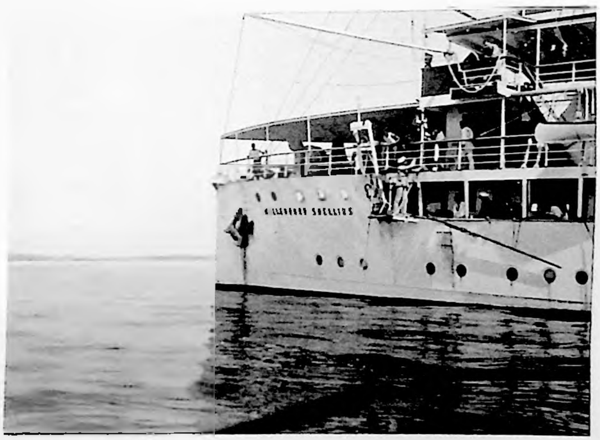

Fig. 4. Heavy bottom sampler. Length 4 metres.

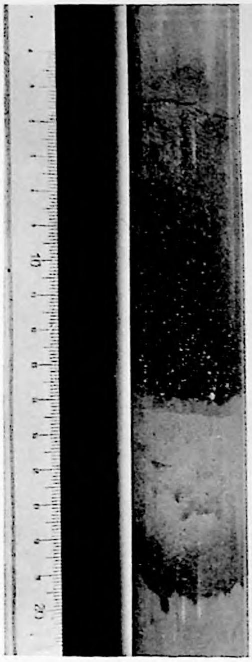

Fig. 1. Station nr. 358. Two coarse layers grading upwards into finer deposits. Procured by the heavy sampler.

Fig. 2. Detail of upper layer seen in fig. 1.

Fig. 3. Station nr. 189 Vague layers showing up in the glass tube of the sampler.

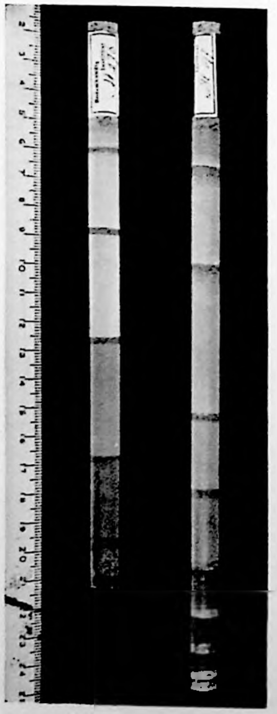

Fig. 4. Grades resulting from mechanical analyses as they were received from Dr. Hardon, Buitenzorg.

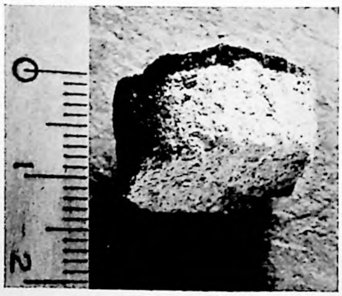

Fig. 5. Disk of marl with thin cover of manganese, procured at 1850 m, station 156, by the Ekman bottom sampling tube.

SNELLIUS-EXPEDITIE

WETENSCHAPPELIJKE UITKOMSTEN DER SNELLIUS-EXPEDITIE

ONDER LEIDING VAN

P. M. VAN RIEL

DIRECTEUR VAN DE FILIAALINRICHTING VAN HET NEDERLANDSCH METEOROLOGISCH INSTITUUT TE AMSTERDAM

VERZAMELD IN HET OOSTELIJKE GEDEELTE VAN NEDERLANDSCH OOST-INDIË AAN BOORD VAN H. M. WILLEBRORD SNELLIUS

ONDER COMMANDO VAN

F. PINKE

LUITENANT TER ZEE DER 1e KLASSE

1929–1930

UITGEGEVEN DOOR DE MAATSCHAPPIJ TER BEVORDERING VAN HET NATUURKUNDIG ONDERZOEK DER NEDERLANDSCHE KOLONIËN EN HET NEDERLANDSCH AARDRIJKSKUNDIG GENOOTSCHAP

GEDRUKT DOOR EN TE VERKRIJGEN BIJ

E. J. BRILL — LEIDEN

THE SNELLIUS-EXPEDITION

IN THE EASTERN PART OF THE NETHERLANDS EAST-INDIES 1929-1930

UNDER LEADERSHIP OF
P. M. VAN RIEL
DIRECTOR OF THE AMSTERDAM BRANCH OFFICE OF THE
NETHERLANDS METEOROLOGICAL INSTITUTE

▼

VOLUME V

GEOLOGICAL RESULTS

PART 3

BOTTOM SAMPLES

SECTION II

THE COMPOSITION AND DISTRIBUTION OF THE SAMPLES

BY

Ir. GERDA A. NEEB

1943

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PREFACE

The interesting work of examining the bottom-samples from the Snellius-expedition was offered to me by the geologist of the expedition, Dr. Ph. H. Kuenen, through the friendly intermediation of Prof. Dr. C. H. Edelman. I am greatly indebted to Prof. Edelman for the hospitality of the Geological Laboratory of the Landbouw Hoogeschool at Wageningen, which he extended to me for my purpose and for the help given by him and Dr. R. D. Crommelin in the examination of the minerals contained in the samples.

The drawing of the leucite-bearing glass from the Batoe Tara was kindly undertaken by Miss M. J. C. Schokker of Wageningen.

To the directors of the Typographical Survey, L. A. M. Ottenhoff and J. H. C. M. van Buitenen my thanks are due for their cooperation in the execution of the maps accompanying this work.

Prof. Edelman and Dr. Kuenen have been so kind as to read through my manuscript and I should like here to express my thanks to Dr. Kuenen for his many useful suggestions and remarks.

Finally I should like to thank Mrs. Kuenen-Wicksteed for the satisfactory conclusion of the work by her translation.

INTRODUCTION

The bottom samples were collected by the geologist of the Snellius-Expedition, Dr. Ph. H. Kuenen, in the eastern part of the Netherlands East Indian Archipelago. In section I he has described the methods of collecting.

The data in table 2, with the exception of the column „Type of sediment" were provided by Dr. Kuenen.

Dr. H. J. Hardon superintended the mechanical analysis of the greater part of the bottom samples and the humidity and carbonate of lime determinations, at the „Bodemkundig Instituut" at Buitenzorg. Thanks to the friendly cooperation of this Institute I received most of the samples in a condition directly suitable for my examination. Of the remainder of the samples, mostly small ones, a part were received in their original condition, while of a few, marked in table 2 by an asterisk, I had only a preparation of the sand fraction mounted in Canada balsam, at my disposition.

The purpose of the mineralogical examination of the deep-sea deposits is to ascertain their nature and distribution and to trace as far as possible what transformations take place on the sea-floor. For this purpose it was necessary to investigate both the mineral and organic constituents of the samples.

The minerals have been minutely examined, while of the organisms present in the samples only a general account can be given. Miss W. S. S. van Benthem Jutting, keeper at the Zoological Museum at Amsterdam, assisted most kindly with regard to the Mollusca, Lamellibranchiata, Gastropoda and Scaphopoda.

With a view to extending our knowledge of the composition of the sediments and further for rendering a comparison with former investigations of samples from these parts more trustworthy, Dr. J. Ch. L. Favejee was kind enough to carry out röntgenographic analyses of the clay fractions of some samples, at Wageningen.

The results of earlier research on the bottom deposits of the eastern part of the East Indian Archipelago have been included as far as possible in constructing the map of the sediments.

CHAPTER I

METHODS OF RESEARCH

A. MECHANICAL ANALYSIS

Before describing the manner in which the research was carried out, we may here give a short account of the mechanical analysis as it is performed at the „Bodemkundig Instituut" at Buitenzorg. The method was introduced about 1910 by Mohr (107, 108) and has been generally adopted in the Netherlands Indies (57). The soil is divided into gravel, that is particles of more than 2 mm diameter and 10 fractions of the following diameters:

1:	2 — 1	mm.
2:	1 — 0,5	„
3:	0,5— 0,2	„
4:	0,2— 0,1	„
5:	0,1— 0,05	„
6:	50 —20	μ
7:	20 — 5	μ
8:	5 — 2	μ
9:	2 — 0,5	μ
10:	< 0,5	μ

This method follows the prescriptions laid down in the 24th Bulletin of the Bureau of Soils at Washington (11, 56) and combines them with a classification founded upon the difference in rate of sinking for particles of various sizes. In the latter especially use is made of the results by Williams-Fadejeff (184) and Atterberg (3); Mohr tested these investigations on tropical soils.

The method of analysis is briefly this: 10 Grammes air-dried material from which the gravel fraction has been extracted by sieving is mixed with 100 cm^3 distilled water, to which is added 10 drops of 10% ammonia solution. The bottles containing this soil suspension are shaken for 4—6 hours in pans provided for the purpose, to promote the disintegration of the particles.

After this soil and water are centrifuged for 2 minutes in glass tubes of 27 by 170 mm at the rate of 1000 revolutions per minute. The particles of less than 5 μ can then be poured off into glass cylinders of ± 25 cm height and 8,5 cm diameter. The remaining sediment is stirred up by a jet of water under pressure and the centrifuging and pouring off is repeated until the liquid poured off does not become any clearer (about 8—12 times).

The residue in the tubes is repeatedly stirred up by a jet of water under pressure and allowed to settle one minute per cm depth of liquid for the separation of particles of 5—20 μ diameter, that is of fraction 7.

The same process is applied to the remaining portion, allowing 5 sec. per cm liquid for settling to separate the particles of 20—50 μ.

The remaining sand fractions larger than 50 μ are dried and weighed and divided by sieving into 5 fractions, each of which is weighed separately (fr. 1—5).

The particles smaller than 5 μ collected in the glass cylinders are again divided into particles of 5—2 μ and particles smaller than 2 μ by filling up the liquid to 20 cm and allowing 24 hours to settle (this is done twice).

The separation of fraction 9 from 10 is made by filling the liquid to 20 cm and after stirring the suspension allowing it a week to settle. The liquid which is then syphoned out contains the fraction

smaller than 0,5 μ (fr. 10) which is sucked off through filter cones and like the other fractions dried on the water bath.

There is one objection to this method, namely that an ammonia solution of only 0,1% is used for peptising the soil samples. This objection applies especially to soil containing calcium carbonate and magnesium carbonate, when an agglutination of very fine clay particles may occur which will erroneously be deposited in the fractions 8 and 9. Even soils containing no $CaCO_3$ or $MgCO_3$ but which have a base complex strongly saturated with lime, will sometimes show this phenomenon. On the other hand the method yields values for these soils also, which can be well duplicated, while it causes no decomposition of the soil due to the use of strong chemicals, such as hydrochloric acid. Thus the objection raised cannot be considered as serious in the case of competent interpretation of the results yielded by the mechanical analysis. For it is only by comparing similar soil types that generally speaking mechanical analyses can become valuable.

The method described has moreover two special advantages for the sediments formed in the sea, namely:

1. by this method the constituents formed of calcium carbonate are preserved and these occur in many and varied forms, thus constituing an important part of the samples.

2. the aggregates which have formed in foraminiferal tests etc. are preserved in their original form, so that they can be examined as such. To these belong glauconite, limonite, pyrite and clay casts or casts composed of various of these substances, which have retained the form of foraminiferal chambers etc.

B. MINERALOGICAL INVESTIGATIONS

The manner in which a mineralogical examination of sediments is carried out depends upon:

1. the object of the research
2. the nature of the material to be examined.

If the object is to establish the nature of the deposits on the sea floor, not only the minerals and their origin must be determined but also the organic substances, which consist chiefly of calcium carbonate and silica. Further it is important to establish what secondary formations may occur in the sediment.

The whole of the sand fraction must therefore be examined and every method which entails treatment with hydrochloric acid is unsuitable, as not only the calcium carbonate is dissolved, but secondary minerals may also be attacked.

The question now arises whether in making complete preparations of the various sand fractions justice can be done to the mineralogical examination, especially that of the heavy minerals. This depends upon the nature of the mineral particles and the proportions in which the mineral and organic particles occur, e.g. Coral and Globigerina Muds may have a low mineral content. If both the mineral content of the sample and the relative content of heavy minerals are low, a separate examination of the heavy minerals is necessary.

In the Netherlands the sandy sediments consist chiefly of quartz, while felspar takes the second place and the content of heavy minerals is very small. Consequently it is natural that Edelman and Doeglas (46, 47, 48) base their classification of sediments upon sediment-petrological provinces derived from the „heavy mineral" research, i.e. from the quantitative composition with regard to the minerals with a specific gravity greater than 2,9. This method is also generally applied in England and America.

By sediment-petrological province is meant a complex of sediments which form a natural entity by their distribution, age and origin. According to the scientists mentioned, to understand the elements of which a sediment-petrological province is composed demands a large number of observations as widely scattered as possible, so that the accidental (and abnormal) variations in the province shall be recognised as such.

Only after the regional distribution of the heavy mineral associations of the sediment-petrological provinces has been ascertained the investigation following this method of research will proceed to examine the connection of these associations with the material occurring in the regions from which they may have been derived, that is, to the search for the region of origin.

The material of the Snellius-expedition is not suitable for constructing sediment-petrological

provinces based upon heavy mineral research, which demands a much closer net of samples. Moreover, the nature of the material renders an exclusive examination of the heavy minerals undesirable for the majority of the samples for the following reasons:

1. in the frequent basic volcanic material the content and the habitus of the volcanic glass belonging to the light fraction may give important indications as to the origin.

2. the light minerals of the terrigenous material show great quantitative variations in composition which are decisive for the determination of the nature of the material, as will be shown in chapter IV.

3. the relative content of light minerals is higher in the basic volcanic material derived from recent ash eruptions than that which is formed from older basic volcanic rocks.

4. for the mutual differentiation of the various recent basic volcanic deposits the light minerals are no less significant than the heavy ones. The light minerals here are usually only basic plagioclase and volcanic glass, sometimes also andesitic or basaltic grit.

As Mohr and White (110) and others have shown for the Gg. Kloet on Java the grain-size of the ash decreases with growing distance from the active volcanoes, concomitant with a decrease of rock-grit, plagioclase and heavy minerals in the ash and with an increase of volcanic glass. This is affected by the direction of the wind and it is probable that ocean currents will also influence the mechanical and mineralogical composition of the ash.

When there are several deep-sea samples derived from the same volcano, the results of the mechanical and mineralogical analysis taken together will indicate the direction from which the material is derived, without its being known with certainty beforehand what is the mineralogical composition of the ash produced by the volcano in question. This will be even more marked when the samples all belong to the same eruption.

The material of the 6 sand fractions was therefore examined without preliminary treatment; each fraction was taken separately because:

1. the composition both of the minerals and the calcareous particles differs strongly in the successive grain fractions.

2. the diagrams which represent the mechanical analysis show various peaks, the meaning of which can only be ascertained with certainty by a separate examination of the fractions; this throws light upon the nature of the deposits.

3. when various types of sediment appear in mixed form the ratio and the nature of the mixture is determined by a separate examination of the fractions in connection with their mechanical composition.

The content of gravel and the two coarsest sand fractions was usually low in the samples examined, so that the number of grains was often insufficient for counting. According to the nature of the material, they were immersed in nitrobenzol or examined without using any liquid. In only a few cases, e.g. for better distinction of the contents of foraminifera, a treatment of part of the material with hydrochloric acid was desirable.

Canada balsam preparations were made of the finer fractions (fr. 3—6). The quantitative composition of the material was determined by field-counting i.e. by counting the grains in a number of fields of vision. This method was preferred to the line-counting as it can be done more rapidly. In line-counting, that is the counting of all grains which pass the centre of the cross wires when the slide is moved zigzag with the aid of a cross-table, the effect of the uneven sizes of the grains is better eliminated. As the various fractions were examined separately this objection to the field-counting was eliminated. A possible effect of inequality in the distribution of the grains in the Canada balsam preparations was limited by choosing the areas to be counted along the diagonals of the slide. The number of grains counted in a preparation depends upon the number of differing particles occurring in the fraction under consideration. It varies between 200 and 500.

Baak (4) suggests for the examination of heavy minerals the counting of 100 transparent grains, while he also determines the percentage of opaque grains. The number of different minerals that are included in these countings is 6 at least and 17 at most.

Drijden (45) has calculated the probable error for various mineral percentages in countings of heavy minerals. He shows that accuracy increases proportional to the root of the number of grains counted and that it is greatest for the most frequent components. He considers that it is sufficient to count 300 grains for heavy mineral research.

When the number of different components becomes greater the number occurring in low percentages also increases; and at the same time the inaccuracy of these percentages. The number of grains to be counted is therefore raised with an increase of different kinds, these kinds for preparations of total sand fractions rose to no less than 35. The number of different kinds of particles is largest in the finest sand fractions.

If it proved necessary the content of certain light minerals such as sanidine, leucite, zeolites etc. was examined by immersion in liquids of known refractive indices, according to Schroeder van der Kolk's (149) method.

For components with a very small percentage per fraction the content was determined in proportion to the total number of grains in the preparation. If the heavy minerals formed the components which were present in very small quantities, they were first separated and then examined. The separate investigation of heavy minerals therefore took place either as supplementary research for a number of samples or as check in such cases where practically no heavey minerals could be demonstrated, as in the terrigenous sediment 363 and the Coral Muds 124 and 129. It appeared that only very fine terrigenous sediments, or this material mixed with Globigerina Ooze have a very low content of heavy minerals. In these cases the heavy minerals occur almost entirely in the fractions 100—50 μ and 50—20 μ, especially in the former. This fraction, therefore, was made use of for supplementary investigation of heavy minerals. The treatment was carried out in the usual way by first treating with hydrochloric acid and then applying the separation with bromoform.

It should here be emphasised that it is owing to special circumstances that fraction 100—50 μ was found most satisfactory for investigating the heavy minerals. This rule should not be regarded as of general application, as appears at once when the mineralogical composition of the volcanic sediments is examined. Amongst these there are several which have the highest heavy mineral content in fractions 0,2—0,1 mm and 0,5—0,2 mm. In 1938 Sindowsky (152) suggested that all sediment petrographers should restrict the investigation of heavy minerals to the fraction 0,1—0,2 mm as in his opinion the heavy minerals are most concentrated there. When tested by the material of the Snellius-expedition this proposal is found to be unsatisfactory.

The applicability of such a method is limited to the region for which it was elaborated. This is another proof that the manner in which a research should be carried out cannot be decided without regard to the composition of the material to be investigated.

CHAPTER II

CLASSIFICATION OF THE SEDIMENTS

The first system of classification of deep-sea sediments was given by Murray and Renard (115) in 1891, when they examined the bottom-samples from the Challenger-Expedition, which had cruised through all the oceans in 1872—1876. This classification distinguished ,,*Pelagic deposits,* formed in deep water removed from land" and ,,*Terrigenous deposits,* formed in deep and shallow water close to land masses".

The pelagic deposits are divided into ,,Red Clay, Radiolarian Ooze, Diatom Ooze, Globigerina Ooze, Pteropod Ooze".

The terrigenous sediments are classified as: ,,Blue Mud, Red Mud, Green Mud, Volcanic Mud and Coral Mud".

Further a distinction is made between ,,Shallow Water Deposits", between low-water mark and 100 fathoms, and ,,Littoral Deposits", between high and low-water marks.

This classification is used by Böggild (8) for the samples of the earlier expedition to the easterly East Indian Archipelago, the Siboga-expedition. He met with Red Mud, Globigerina Ooze, Blue Mud, Volcanic Mud, Coral Mud and Sand and Shallow Water Deposits.

In neither the Snellius-expedition, nor in the earlier samples from this region have Diatom Ooze or Pteropod Ooze been found, while only once and that at a time when the sampling was unsatisfactory, (cf. p. 64) a sample of Radiolarian Ooze was found. These types will therefore be left out of consideration.

Green Mud is not recorded by Böggild; the Challenger-expedition found a few samples of Green Mud in this region. The Snellius samples at St. 280 have a decidedly green colour, while some 20 more samples of a more or less green colour are included in Table 2.

Green Mud is characterised as being coloured by a great abundance of glauconite grains. The objection to the term is that every sediment with a green colour is included under the heading without being certain whether it really contains glauconite. Neaverson (119) says in his description of the samples collected by the ,,Discovery" in the southern Atlantic Ocean: ,,In many of the so called Green Muds in the Discovery collection, no grains of glauconite have been noted. In these instances the green colour appears to be due to the presence of chlorophyll, the green colouring matter which occurs in the chromatophores of diatoms and other algae, though often masked by other pigments". He draws the conclusion that ,,mere colour is no criterion of origin".

Amongst the samples from the Snellius-expedition of a green colour nr. 280 contains no glauconite at all, while of the remaining 20, 8 contain a certain amount of glauconite. In some cases the green colour may be caused by chlorite. On the other hand by no means all samples with a glauconite content are green in colour. Glauconite occurs in Globigerina Ooze, Coral Mud and Terrigenous Deposits. In the Terrigenous Deposits the content is never so high that they can be called ,,Glauconitic Mud", so that all green coloured Terrigenous Deposits are included with the so-called ,,Blue Mud" as ,,Terrigenous Deposits".

,,Red Mud" was found only once and that as substratum (28—55 cm) in sample 194 raised 60 km west of the volcano Batoe Tara. The upper layer of this sample is greenish (0—28 cm) and there is a sharp line between the two layers. Yet the mechanical analysis and the mineralogical composition of the two samples show practically no difference between the two layers. The mineral percentage in the upper sample, however, is higher, while the lime content of the upper sample is also

considerably higher. The presence of this lower layer of Red Mud cannot be explained without knowing more about its distribution.

From the classification by Murray and Renard the following types have been retained: Globigerina Ooze, Red Clay, Coral Mud and Volcanic Mud.

1. Globigerina Ooze, in agreement with Böggild, includes the samples with a $CaCO_3$ content of more than 30%, of which the greater part consists of pelagic foraminifera.

2. Red Clay, that is the more or less brown to red deposits which usually contain manganese nodules or a film of manganese, usually formed far from land masses in the open ocean at great depths. This kind of sediment was first found by the Challenger-expedition. It covers large areas of the deep seas.

At first it was believed that „it was to be the most minutely divided material, the ultimate sediment, so to speak, produced by the disintegration of the land, which, held in suspension in seawater, was distributed to great distances by ocean currents".

Later Murray and Renard (115) ascertained, by means of mineralogical and chemical research, that the minerals in Red Clay were principally formed by basic volcanic material. By analogy with what happens on land they felt justified in assuming that the Red Clay was formed in situ from basic volcanic material, while they ascribed a subordinate importance to finely divided clay suspension derived from the land, as a component. They examined the minerals and the particles of Red Clay with a diameter of more than 0.05 mm. These particles proved to contribute on an average only 5.6% of the entire sample.

The microscopic and röntgenographic research by Correns (37) and Mehmel of material collected by the „Meteor-expedition" in the Atlantic Ocean, have shown that the composition of the clay fractions of Red Clay. Blue Mud and Globigerina Ooze are not essentially different within certain areas. In decreasing frequency they were found to contain calcite, quartz, mica, halloysite, kaolinite, montmorillonite, felspar, augite and aragonite.

Although the mutual proportions of the minerals may vary in Red Clay, Globigerina Ooze and Blue Mud, according to the conditions under which the sediment was formed, there is no difference in the nature of the clay-minerals. Correns concludes from this that the Red Clay as well as the Blue Mud and the clay-fractions of the Globigerina Ooze are for the most part of terrigenous origin. His conclusion is supported by the fact that:

a. quartz and mica occur in almost all the samples, that these are very stable minerals and cannot be considered as secondary minerals.

b. Correns considered the distribution of the clay minerals in the region of research in the Atlantic Ocean to be connected with the prevailing ocean currents; this refers to the clay minerals: halloysite, kaolinite and montmorillonite.

Correns (38) further deduces from the similarity of the mechanical composition and the composition of the clay minerals in a Red Clay sample of 86 cm length that mica, halloysite and kaolinite do not occur as secondary minerals in Red Clay. The rate of settling of this sample was estimated at 60.000 years.

The fact that the sand fractions of the Red Clay samples from the Challenger-expedition, which form only a small part of the samples, usually contain a large amount of volcanic material, may be accounted for by the smaller rate of settling of Red Clay compared to that of Blue Mud and Globigerina Ooze, so that the volcanic material is less diluted in the Red Clay; however, material derived from volcanic eruptions could be shown in smaller amounts in the Globigerina Ooze also.

The original opinion of the „Challenger naturalists" concerning the formation of Red Clay proves to be the most correct. Murray and Renard's conclusions, based principally upon the examination of the sand fraction, in this case a small part of the sample, led to incorrect inferences.

The red colour of the deposit cannot, therefore, be attributed to submarine weathering; it is due to the oxydation of the extremely slowly deposited clay particles in the deeper waters, rich in oxygen, of the open ocean which flow from the poles towards the equator.

Amongst the samples from the Snellius-expedition there are only a very few that belong to the Red Clay. At the same time we consider it important to deal with this sediment at some length as both the name and the distribution of the sediment called by Molengraaff (114) „ontkalkt diepzee slik *)" and the distribution of Volcanic Mud need revision in connection with the further light thrown upon the formation of clay fractions in deep-sea deposits by röntgenographic research.

The name „ontkalkt diepzee slik" *) is given by Molengraaff to all deep-sea deposits poor in lime below 4000 m., which are not deposited far from the coast. Now that Red Clay is recognised as largely terrigenous this distinction has become superfluous in so far as these deposits betray a certain amount of oxydation by their red colour or by the formation of mangenese oxides.

There are moreover, other reasons for rejecting the term „ontkalkt diepzee slik".

Molengraaff registers deep-sea mud poor in lime especially in the Banda sea and the Celebes sea, i.e. in the areas where volcanic sediments are largely distributed, that is to say sediments in which the lime content is very much diminished both by the solution of calcium carbonate and the large admixture of volcanic material. Moreover in the basins a more rapid sedimentation of terrigenous material may be expected than in the open ocean; sediments poor in calcium carbonate are by no means confined to areas lying at more than 4000 m depth.

Moreover the decalcification of sediments is much less dependant up the depth than upon the presence of cold oxygenated currents which facilitate the formation of carbonic acid and thus the solution of calcium carbonate. Thus in contrast to the sediments in the Celebes sea Globigerina Ooze is found in the Soeloe sea at greater depths than 4000 m as here, according to observations of the Snellius-expedition, there is a slower flow of oxygen-poor water and because the temperature is comparatively high, consequent on the high level (some 400 m) of the sill (130) between the Soeloe sea and the China sea. All these arguments plead against the use of the term „ontkalkt diepzee slik". In the light of the röntgenographic research on deep sea sediments, the use of this term, which is applied only to deep deposits, prevents sediments which correspond to each other being indicated by the same term, in casu as Terrigenous Muds; e.g. the Terrigenous Muds from St. 360 and 361 raised from 1100 m and 2650 m respectively, have as low a relative lime content as that of the sample 362 from a depth of 7350 m.

To summarise it may be said that Terrigenous Muds with a relatively low calcium carbonate content may be formed in various ways: dilution of the lime by rapid deposition of volcanic or terrigenous material or solution of the lime by oxygenated cold currents which ventilate the water in the basins. The depth at which the sediment is deposited is not of primary importance to the lime content of the sediment. There is therefore no reason to distinguish „ontkalkt diepzee slik" as well as Terrigenous Mud.

3. Coral Mud and Sand are sediments rich in lime, which contain only a small amount of pelagic foraminifera in addition to coral particles, algae etc.

4. Terrigenous Mud, includes the terrigenous deposits formed of material carried off from continents and islands, in so far as they are not derived from still active volcanoes. This group, therefore, embraces the former Blue Mud and Green Mud; moreover the sediments are also included which derive their lime from material coming directly from continents or islands.

5. Volcanic Mud consists principally of material derived from recent volcanoes.

The röntgenographic examination of the clay fractions of some of the Snellius samples demonstrated that samples which the mineralogical examination of the sand fractions above 20 μ would have indicated as purely volcanic might yet have terrigenous material mixed with them (cf. Chap. VI). A part of the sediments therefore, formerly counted as Volcanic Muds must be regarded as mixed deposits. They are indicated as:

6. Volcanic + Terrigenous Mud, this type of sediment usually appears as a true mixture, that is to say, perceptably different layers of volcanic and terrigenous material are usually not present. This may be due either to a limited amount of ash being thrown out during a particular eruption or to the slow rate of settling of a volcanic ash with a high glass content or even to the effect of submarine currents.

As the minerals in practically pure volcanic ash, like sample 167, show no signs of decomposition not much significance can be attached to a secondary formation of clay minerals from these ashes in sea water. The ash at St. 167 is derived from the Tambora eruption of 1815 (cf. Chap. IV) and was not covered by other deposits; it had, therefore, been in contact with the sea water for 115 years at the time it was raised. As the habitus of this ash proved to be the same as of fresh volcanic ash, the weathering in seawater must certainly be very much slighter than on land. The present writer (120,

*) That is deep sea mud with an abnormally low lime content.

121), in sand fractions of soil originating from about 30 years old volcanic ash, could clearly demonstrate a certain amount of secondary minerals and part of the minerals were affected. Seawater, compared to the effect of air, rain and wind seems rather to act as a preservative for the minerals and volcanic glass. Correns (37) (p. 291) had the same experience; he maintains that seawater is a weathering solution which in contrast to rainwater is a solvent of very little activity, and that only chemical transformation is to be expected of ions whose concentration in seawater is low compared to that of the sediments, as is the case with iron and manganese.

Purely volcanic ash shows a mechanical composition in which the peak lies in one of the sand fractions, usually in fraction 100—50 μ or 50—20 μ, while the amount of clay fractions is neglegible. With an increasing content of clay fractions in the deep sea samples the content of terrigenous material increases, as is shown by the examples given in Chap. VI. In cases where volcanic ash and terrigenous material are mixed, therefore, this can be learned from the mechanical analysis, where it is not evident from the mineralogical examination of the fractions greater than 20 μ. Deposits which consist of much fine material may contain 60% terrigenous components and yet show only volcanic material in the sand research. Examples of this occur in the deep basins at a greater distance from the coast, e.g. in the Flores sea.

The type of sediment of mixed volcanic and terrigenous components is widely distributed in the area of the East Indian Archipelago in which the research was carried out.

We have now distinguished six primary types. A subdivision of these, according to the inorganic material, is discussed in Chap. IV.

The name „Shallow Water Deposit" is given to the deposit 157 rich in lime which contains no coral particles, in accordance with the usage of other investigators, who applied the name to similar sediments formed in shallow water.

CHAPTER III

EARLIER RESEARCH

The earlier researches are dealt with by Prof. G. F. A. Molengraaff (114) in the chapter „Geologie" of the book „De Zeeën van Nederlandsch Oost-Indië", which appeared in 1922. These are:

1. In 1858 A. F. Siedenburg, commander of the Netherland naval vessel „Cachelot", raised samples from great depths for the first time when sounding in the Banda-sea. Five of these samples have been examined by Harting (67). They were small samples, obtained by attachment to fat. Harting removed the fat by treatment with benzol and examined the remaining powder under the microscope.

Samples Ca 2 and Ca 3, according to Harting are Globigerina Ooze and Radiolarian Ooze, as given by Molengraaff. Sample Ca 1 is called Volcanic Mud by Molengraaff, but Harting describes it as very fine clay and the minerals contained in it he calls „a few larger sharp angular fragments of various undefinable minerals". This vague description does not justify the inclusion of the sediment in Volcanic Mud, while the consistency being very fine clay, indicates a principally terrigenous origin, as has been explained in Chapter II. The Snellius sample 231 raised in the same neighbourhood confirms this opinion, being a Terrigenous Mud with a sporadic admixture of volcanic material.

The two samples Ca 4 and Ca 5, classified by Molengraaff as „ontkalkt diepzee slik" were attributed by Harting to „fine clayish brown mud", in which he detected particles of pumice and in which „the number of larger fragments of various minerals is conspicuous". This sample we have classified as Volcanic Mud, considering its position with regard to the Goenoeng Api and to samples 245 and 246 of the Snellius-expedition. Sample Ca 5, described as „light grey soft muddy clay with a few larger always sharpsided fragments", we have classified amongst the mixed volcanic and terrigenous sediments, chiefly because of its consistency.

2. In 1874 and 1875 in the Challenger-expedition soundings were made at 21 stations in the region of the Netherland East Indian Archipelago, marked on the map, and bottom-samples were obtained. These samples are described by Murray and Renard (115).

The Challenger samples have been the most elaborately examined of the older researches and the most clearly described. In consequence of the somewhat modified definition of Globigerina Ooze used by Böggild (8) on his map, which we here adopt, samples C 195 and C 214 instead of being reckoned as Blue Mud should be included in Globigerina Ooze, as both possess a $CaCO_3$ content above 30% of which more than half consists of pelagic foraminifera.

The rest of the samples of Blue Mud belong, according to the definition of Murray and Renard, to the Terrigenous Muds; the small sample C 197 however probably contains an admixture of volcanic material.

The samples which they define as Globigerina Ooze and Red Clay are classified in the same way on our map I.

Of the samples of Green Mud C 191 has a low lime content and a high content of fine fractions; this sediment is therefore reckoned to the Terrigenous Muds. Sample C 191A contains 40,2% $CaCO_3$ of which 30% is pelagic foraminifera and is therefore classified as Globigerina Ooze. Sample C 200 was small and little description is given, neither is mention made of its containing glauconite, although it is mentioned in samples C 191 and C 191A; on this account it has been left out.

There are 5 samples of Volcanic Mud of which C 193 and C 199 are classified as mixed type of

volcanic and terrigenous material. They contain 35% and 50% of fine fractions respectively. Samples C 198 and C 199 are both about the same. However since 1874, when these samples were raised, there have been numerous eruptions of the submarine volcano Banoea Woehoe, lying to the east of C 198. Eruptions (123) are known to have taken place in the years 1889, 1895 and 1904 and a volcanic activity lasting for several months in 1918—1919. It may be assumed that the settling of the volcanic ash at C 198 has greatly increased as sample 53 of the Snellius, which is 48 cm long and was raised much further from the Banoea Woehoe, consists almost entirely of material of the Banoea Woehoe. Moreover C 198 contains a considerable amount of Banoea Woehoe material, considering its composition, which is further treated in Chapter IV.

3. In 1875 the „Gazelle" collected 12 bottom-samples, lying in, or in the neighbourhood of, the East Indian Archipelago, 8 of which have been examined by Gümbel (63).

At St. G 94 a sample of Red clay was taken, containing sporadic volcanic material, as well as quartz and mica and also manganese nodules.

Samples G 95, G 96 and G 98 are called Volcanic Mud by Molengraaff. The Snellius samples from this area show an admixture of older volcanic material, while there are not more than traces of recent volcanic material. The rounded quartz in G 95 and G 96 and the hornblende and mica demonstrated by Gümbel in G 98 can certainly not originate from surrounding volcanoes, all of which yield pyroxene andesitic to basaltic material. The samples are therefore classified as Terrigenous Muds. Sample G 102, which Molengraaff called Blue Mud belongs also to the Terrigenous Muds as does the sediment G 105 the terrigenous origin of which is indicated by the minerals contained in it.

Samples G 103 and G 104 are called Globigerina Muds by Molengraaff, which in the case of G 104 must be a slip. Von Gümbel says of it: „Meeresgrundproben St. 103 und 104 aus 832 und 1820 Meter Tiefe stimmen in der Hauptsache überein, nur dasz die aus grösserer Meerestiefe stammenden Ablagerungen (= G 104) aus feineren Gemengtheilen bestehen und weniger Foraminiferen, dagegen mehr Radiolarien enthalten". Sample G 104 is, therefore, also included in the Terrigenous Muds. In these samples von Gümbel demonstrated quartz and volcanic minerals, as well as glauconite.

The 4 samples not examined by von Gümbel of which Molengraaff calls G 97 = Blue Mud, G 99 and G 100 = Volcanic Mud and G 101 = Coral Mud, are here given the same names, except that G 99, in accordance with the further data, is placed in the region of mixed volcanic and terrigenous material.

4. The samples collected in 1899 by the „Valdivia" all lie to the west of Sumatra and are therefore outside the area explored by the „Snellius".

5. In 1899 and 1900 the first larger expedition was made to this area by the Siboga, especially to the eastern part of the Archipelago. The bottom samples of 102 stations have been examined by Böggild (8).

There were 27 samples of Globigerina Ooze and 6 samples of Coral Mud raised on this expedition which are given on our map in the same way as Böggild classified them.

Of the 21 samples given as Blue Mud 16 are transferred to Terrigenous Mud. The remaining samples of Blue Mud, being those from station S 83, S 84, S 85, S 87 and S 88 lie in the area where the Snellius samples show a greater or less admixture of volcanic material derived from the Oena-Oena. Apparently this escaped Böggilds observation.

The 13 samples which Molengraaff gives as „ontkalkt diepzee slik" were entitled Red Clay by Böggild „mit sehr groszem Bedenken" as he says on p. 16, although he perceived that most of them corresponded to Volcanic Mud or Blue Mud. He considered that in the Celebes sea and in the Banda sea from the coast outwards Terrigenous Deposits, Globigerina Ooze and then the Terrigenous Deposits with low lime content would succeed each other. This succession was not confirmed by the investigation of the Snellius samples, generally speaking, while on the other hand the specific characteristic of Red Clay, namely the oxidised condition, was not manifested by the red colour and the manganese content in any of these samples. All these samples, therefore, should be included in the Terrigenous Muds or Terrigenous + Volcanic Muds, although just how this should be done could not be deduced from Böggilds description, as he does not mention the minerals found in any of the samples. The mechanical analysis gives the separate fractions; the particles smaller than 50 μ, how-

ever are not further distinguished. Except when the samples contain a large amount of sand a mechanical analysis of this sort is not of much use; the clay fractions and the volcanic-ash fractions are not separated, so that no indication is given, whether or to what extent, volcanic ash is contained in the samples. In this case we were satisfied with classifying these samples in accordance with the results of the examinations of the Snellius samples and with those of the earlier expeditions. Thus samples S 92, S 190, S 198, S 233, S 246, S 247 and S 275 are reckoned as Terrigenous Muds and samples S 218, S 223, S 238, S 239, S 242 and S 245 as mixed terrigenous and volcanic sediments. Of these samples only S 242 and S 245 contain any considerable amount of sand in the form of minerals, that is 17.5% and 26.5% respectively.

Böggild gives 22 samples as Volcanic Mud. It must be assumed that in these he found only minerals which could be derived from volcanic eruptions. Eight of these samples are also reckoned as Volcanic Mud on our map, viz. S 5, S 8, S 48, S 135, S 137, S 312, S 314 and 316. The sand percentage and the mineral content of the sand of samples S 5, S 8, S 312, S 314 and S 316 corresponds pretty nearly to these of the sediments 172 and 173 of the Snellius-expedition; while the same may be said of S 48 compared to sample 167 and of S 135 compared to samples 344 and 345. S 135 is situated between stations 344 and 345; moreover Böggild records a high glass content for S 135. The sediment S 137 is reckoned as Volcanic Mud owing to the comparatively high mineral content of the sand fractions combined with the position of the station close to the volcano Makian.

Amongst the mixed Volcanic and Terrigenous Muds 8 samples are classified which Böggild called Volcanic Mud. These are S 10, S 17, S 18, S 62, S 63, S 70, S 128 and S 224. With the exception of S 128 the sandy mineral content ($> 50\ \mu$) of these samples is low, viz. a maximum of 2.3%. On this account S 10, S 17, S 18 and S 70 are comparable to the sediments 178 and 179 of the Snellius. In the same way S 62 and S 63 may be compared to sediment 317A, while S 224 is comparable to sediment 249. Concerning S 128 Böggild says on p. 36 that this sample contains little or no volcanic ash so that it is not comparable to nr. 301 of the Snellius samples, but probably it resembles the andesitic material of the Globigerina Ooze 299. This contains practically no glass and cannot be derived from a recent ash eruption, so that it has been reckoned as a basic volcanic Terrigenous Mud.

The remaining 6 samples, which Böggild reckons as Volcanic Muds, all have a very low sand content, so that taking also the mineralogical examination of the Snellius samples into consideration they cannot be classified as Volcanic Muds. The minerals that Böggild observed in them in the case of S 139 and S 143, may be derived from washed in material of extinct volcanoes from the island of Batjan. S 235 may probably be compared to the Snellius sample 361, which contains in its sand fractions principally basic volcanic material rich in hornblende and biotite, as well as minerals from metamorphic rocks, and a little pumice and volcanic glass from the Banda volcano. S 132 like the Snellius samples 291 and 292 is brought under Terrigenous Muds containing old volcanic material. S 76 according to the mechanical analysis that Böggild gives contains only 0.1% sand coarser than 50 μ, containing no minerals. On what grounds he records this sample as Volcanic Mud is not clear; considering the mineralogical composition of the Snellius samples 31 and 33 there may be material from alkaline rocks in this sample; it then belongs to the Terrigenous Muds, containing older alkaline rock detritus. Sample S 55 has a high content of volcanic glass on which Böggild lays particular stress on p. 36. But if we look up the mechanical analysis of this sample the sand percentage coarser than 50 μ proves to be 2.2% of which 0.7% is formed by minerals. If this be compared with the Snellius sample 146 from the Indian ocean, which should certainly be regarded as terrigenous material on account of its high clay content, with a slight admixture of recent volcanic material, it appears that the sand content coarser than 50 μ in 146 is 3.2% and the mineral percentage larger than 50 μ is 1.6% of which 1.3% is present as volcanic glass. Here apparently there is a high glass content compared to the amount of minerals examined; the total glass content is even higher than in S 55, in 146 it amounts to 3 to 4%, as 25% of the fraction 50—20 μ consists of volcanic glass. The demonstrated glass content of S 55 amounts to at most 0.7%, so that this sample is also reckoned as Terrigenous Mud with a small content of recent volcanic material.

Finally Böggild gives 13 samples as „Shallow Water Deposits", that is to say that they were raised from depths not greater than 200 m. Of these 7 are deposits rich in lime and six with a poor lime content. In so far as the rich sediments contain coral particles they are indicated on the map by a yel-

low colour, this refers to samples S 14, S 15, S 16, S 77, S 125 and S 154. The deposits rich in lime in which no coral particles were found and in which the lime is contributed chiefly by benthonic foraminifera shells, echinoderms etc. are marked on map I with yellow shaded with black. To this S 289 belongs.

Of the sediments poor in lime S 1, S 2 and S 49a belong to the samples rich in clay and poor in minerals, which lie in the area given by Böggild as containing volcanic material, so that they are included in the mixed Volcanic and Terrigenous Deposits. Probably the sand sample S 51 belongs here too, but this is uncertain. Samples S 167 and S 319 lie in the non-volcanic area and are therefore included in the Terrigenous Muds. In S 319 slight amounts of volcanic material occur (cf. Böggild p. 35), corresponding to the composition of the neighbouring samples of the Snellius-expedition.

6. From the Java sea, in 1918 and thereafter, a great number of bottom-samples were raised. They were taken with soundings, made regularly by the then Department of „Landbouw en Nijverheid" (Agriculture and Industry) for the use of the fishery research. These samples, which are derived exclusively from the Soenda shelf were examined by Mohr (109, 114) and White, who made a map of this area, where the samples are classified solely according to the mechanical analysis. They distinguish:

a. gravel, sand and loamy sand.
b. sandy loam.
c. loam.
d. heavey clay.

In the part of the Soenda shelf contained in map I it appears that south of a line running at a latitude of 6°.5 S. from east to west heavy clay is found, while north of this line gravel, sand, loamy sand and sandy loam occur. Of the samples further it is only recorded that they are poor in detritus of organisms, that the clay samples along the coast of Java all contain plagioclase and that quartz sand is absent from them, while in the northern half of the Java sea volcanic components do not occur. The observation that coarser or finer quartz sand and quartz sandy loam compose the bottom of the northern half of the Java sea leads the authors to the conclusion that this area is submerged land adjoining Borneo, Banka and Billiton. The bottom sediments of the northern Java sea can therefore be classified as Terrigenous Muds. The Snellius samples 25 and 26 and the Siboga sample 319 lie in the southern half of the area then explored. Sample 25 and 26, which however, cannot be counted as belonging directly to the coastal area of Java, both contain quartz and further predominently terrigenous constituents, as Böggild records for S 319 on p. 35, although the plagioclase specially mentioned by Mohr is not wanting. Only the mineralogical composition of these three samples can be used for the map of the bottom-sediments, as Mohr and White do not give any separate mineralogical data of the samples they examined.

The stations at which the samples of the „Cachelot", the „Challenger", the „Gazelle" and the „Siboga" were taken are marked on map I, which gives the distribution of the sediments. They are further described below in Table 1.

TABLE 1. List of former stations in the Molucca Seas.

Station	Latitude	Longitude	Depth in m.	$CaCO_3$	SiO_2 as organisms	Fine washings	Type of Sediment
Cachelot							
1	3°51′ S	128° 2′30″E	1782	0			Terrigenous Mud
2	4°12′ S	129°11′ E	2160	> 50			Globigerina Ooze
3	3°52′ S	128°51′ E	3690	0	> 50		Radiolarian Ooze
4	6°40′ S	126°47′ E	4860	0	few		Volcanic Mud
5	4°20′ S	129°26′ E	7200	0	few		Volcanic + Terrigenous Mud
Challenger							
191	5°41′ S	134° 4′30″E	1463	14,0	1,0	84,0	Terrigenous Mud
191A	5°26′ S	133°19′ E	1061	40,2	1,0	57,8	Globigerina Ooze
192	5°49′ S	132°14′15″E	256	8,3	1,0	89,7	Terrigenous Mud

TABLE 1. List of former stations in the Molucca Seas.

Station	Latitude	Longitude	Depth in m.	$CaCO_3$	SiO_2 as orga-nisms	Fine wash-ings	Type of Sediment
192A	5°49′15″S	132°14′15″E	236	79,6	5,0	14,4	Globigerina Ooze
193	5°24′ S	130°37′15″E	5121	trace	5,0	35,0	Volcanic + Terrigenous Mud
194	4°34′ S	129°57′30″E	366	—	—	—	Volcanic Mud
194A	4°31′ S	129°57′20″E	658	—	—	—	„ „
195	4°21′ S	129° 7′ E	2606	31,4	3,0	55,6	Globigerina Ooze
196	0°48′30″S	126°58′30″E	1509	93,7	1,0	4,3	Hard Ground (Limestone)
197	0°41′ N	126°37′ E	2194	—	—		Volcanic + Terrigenous Mud
198	2°55′ N	124°53′ E	3932	—	3,0	52,0	Volcanic Mud
199	5°44′ N	123°34′ E	4755	—	2,0	50,0	Volcanic + Terrigenous Mud
200	6°47′ N	122°28′ E	457	—	—		
201	7° 3′ N	121°48′ E	150	—	—	—	Stones, Gravel.
211	8° N	121°42′ E	4069	14,6	2,0	81,4	Terrigenous Mud
212	6°54′ N	122°18′ E	18	—	—		Volcanic + Terrigenous Mud
213	5°47′ N	124° 1′ E	3749	1,8	5,0	33,3	Terrigenous Mud
214	4°33′ N	127° 6′ E	914	34,3	2,0	43,7	Globigerina Ooze
215	4°19′ N	130°15′ E	4663	—	3,0	92,0	Red Clay
216	2°46′ N	133°58′ E	3063	49,0	1,0	49,0	Globigerina Ooze
216A	2°56′ N	134°11′ E	3658	34,7	1,0	63,3	„ „
Gazelle							
94	12°28′ S	119° 3′30″E	5221				Red Clay
95	11°18′ S	120° 8′30″E	4078				Terrigenous Mud
96	9°56′30″S	121°52′ E	2981				„ „
97	9°58′30″S	122°55′ E	3164				„ „
98	8°48′ S	124°15′ E	3758				„ „
99	7°35′ S	125°27′ E	4243				Volcanic + Terrigenous Mud
100	6°33′ S	126°29′30″E	4243				Volcanic Mud
101	5°27′ S	127°32′ E	1152				Coral Mud
102	2°54′30″S	127°46′30″E	3145				Terrigenous Deposit
103	2°37′30″S	129°19′30″E	832				Globigerina Ooze
104	2°42′30″S	130°46′ E	1820				Terrigenous Deposit
105	0° 5′ S	132°29′ E	4389				„ „

Station	Latitude	Longitude	Depth in m.	$CaCO_3$	Particles < 0.05 mm	Type of Sediment
Siboga						
1	7°27′30″S	113° 8′30″E	37		clay	Volcanic + Terrigenous Mud
2	7°25′ S	113°16′ E	56	1,4	99,3	„ + „ „
5	7°46′ S	114°30′30″E	330	12,9	72,8	Volcanic Mud
8	7°54′ ″S	114°48′48″E	720		sandy clay	„ „
10	7°25′ S	115° 5′ E	600	6,9	clay	Volcanic + Terrigenous Mud
12	7°15′ S	115°15′36″E	289		sandy clay	Coral Mud
14	7° 5′30″S	115°13′48″E	91	85,8	4,2	Coral Sand
15	7° 2′36″S	115°23′36″E	100	59,5	24,9	„ „
16	6°59′ S	115°24′42″E	22	44,6	95,2	Coral Mud
17	7°28′30″S	115°28′ E	1060	3,2	98,7	Volcanic + Terrigenous Mud
18	7°28′12″S	115°24′36″E	1018	2,0	98,3	„ + „ „

TABLE 1. List of former stations in the Molucca Seas.

Station	Latitude	Longitude	Dept in m.	$CaCO_3$	Particles < 0,05 mm	Type of Sediment
48	8° 4′42″S	118°44′18″E	2060	8,3	74,3	Volcanic Mud
49[a]	8°23′30″S	119° 4′24″E	69	2,3	98,2	Volcanic + Terrigenous Mud
51	Molo-Strait		69–91	14,4	9,0	„ + „ „
52	9° 3′24″S	119°56′42″E	959	41,5	25,6	Globigerina Ooze
55	10°24′48″S	121°11′30″E	1456	4,7	97,8	Terrigenous Mud
59	10°22′42″S	123°16′30″E	390	83,9	12,7	Coral Mud
62	7°57′18″S	122° 9′ E	2570	18,9	clay	Volcanic + Terrigenous Mud
63	7°32′12″S	122° 3′30″E	2560	21,7	98,3	„ + „ „
68	6° 1′30″S	120°45′30″E	3110	30,4	99,3	Globigerina Ooze
69	5°35′12″S	120°42′ 6″E	1196	64,0	68,6	„ „
70	6°19′30″S	119°52′ E	1091	27,1	95,0	Volcanic + Terrigenous Mud
74	5° 3′30″S	119° 0′ E	450	48,9	32,5	Globigerina Ooze
76	4°22′ 6″S	118°16′54″E	2029	6,3	99,9	Terrigenous Mud
77	3°24′ S	117°36′ E	59	42,7	30,9	Coral Sand
83	0°40′30″S	118°26′36″E	2400	3,9	97,9	Volcanic + Terrigenous Mud
84	0°40′30″S	119° 4′ E	1624	3,7	99,8	„ + „ „
85	0°36′30″S	119°29′30″E	724	7,0	99,7	„ + „ „
87	0°32′ S	119°39′48″E	655	3,4	99,2	„ + „ „
88	0°34′36″N	119° 8′30″E	1301	16,2	99,1	Terrigenous Mud
92	3° 7′ N	119°22′ E	3975	0	clay	„ „
95	5°43′30″N	119°40′ E	522	91,9	20,2	Coral Sand
101	6°15′ N	120°21′ E	1270	48,7	90,1	Coral Mud
102	6° 4′ 6″N	120°44′ E	535	81,5	43,9	Coral Sand
125	Siau-Islands		27		7,8	„ „
128	4°27′ N	125°25′42″E	1645	29,8	56,0	Volcanic + Terrigenous Mud
132	3°56′42″N	126°25′ E	3302	2,6	98,4	Terrigenous Mud
135	1°34′ N	126°54′ E	1994	16,5	66,3	Volcanic Mud
137	0°23′48″N	127°29′ E	472	0,9	88,9	„ „
139	0°11′ S	127°25′ E	397	19,0	94,1	Terrigenous Mud
143	1° 4′30″S	127°52′42″E	1454	28,4	99,1	„ „
147	0°22′42″S	128°52′42″E	2039	32,7	sand	Globigerina Ooze
148	0°17′42″S	129°14′30″E	1855	36,9	97,3	„ „
151	0°12′42″S	129°48′ E	845	69,2	82,7	„ „
154	0° 7′12″N	130°25′30″E	83	93,0	5,1	Coral Sand
156	0°29′12″S	130° 5′18″E	469	88,8	3,7	„ „
159	0°59′ 6″S	129°48′48″E	411	64,8	14,8	Globigerina Ooze
161	1°10′30″S	130° 9′ E	798	57,1	49,9	„ „
167	2°35′30″S	131°26′12″E	95	14,1	66,1	Terrigenous Mud
170	3°37′42″S	131°26′24″E	924	56,9	55,7	Globigerina Ooze
171	3°46′18″S	131° 9′18″E	470	64,2	clayey sand	„ „
173	3°27′ ″S	131° 0′30″E	567	15,9	94,6	Terrigenous Mud
175	2°37′42″S	130°33′24″E	1914	9,2	99,9	„ „
178	2°40′ S	128°37′30″E	835	12,7	89,2	„ „
182	3°46′ S	127°42′ E	3702	2,4	96,8	„ „
189	2°48′18″S	127°13′ E	2124	4,2	clayey sand	„ „
190	2°19′ S	126°23′30″E	4082	0,0	99,2	„ „
191	2° 8′42″S	126°10′24″E	2694	12,6	clay	„ „
198	2°49′24″S	126°17′ E	4113	4,2	91,1	„ „

TABLE 1. List of former stations in the Molucca Seas.

Station	Latitude	Longitude	Depth in m.	$CaCO_3$	Particles < 0,05 mm	Type of Sediment
208	5°39′ S	122°12′ E	1886	37,8	99,0	Globigerina Ooze
210	5°28′ S	121°23′30″E	2218	26,9	98,6	Terrigenous Mud
211	5°40′42″S	120°45′30″E	1158	59,9	76,3	Globigerina Ooze
212	5°54′30″S	120°19′12″E	462	39,1	95,9	″ ″
214	6°30′ S	121°55′ E	2796	33,6	97,7	″ ″
216	6°49′ S	122°43′ E	2190	37,6	96,5	″ ″
217	6°40′36″S	123°14′42″E	2477	36,8	93,0	″ ″
218	6°24′12″S	123°39′ 6″E	3912	23,9	98,3	Volcanic + Terrigenous Mud
221	6°24′ S	124°39′ E	2798	44,3	80,3	Globigerina Ooze
222	6°10′ S	125°35′30″E	3215	36,6	89,1	Globigerina Ooze
223	5°44′42″S	126°27′18″E	4391	2,1	85,6	Volcanic + Terrigenous Mud
224	5°34′ S	127° 4′ E	2952	24,1	89,9	″ + ″ ″
227	4°50′30″S	127°59′ E	2081	66,9	52,2	Globigerina Ooze
228	4°32′30″S	128°30′30″E	2527	35,1	83,9	″ ″
229	4°23′ S	128°45′30″E	1980	76,2	19,5	″ ″
233	3°56′ S	128°25′30″E	4489	7,0	clay	Terrigenous Mud
235	3°42′ S	129° 2′54″E	1910	14,7	98,5	″ ″
238	4°19′30″S	129°20′48″E	4428	0	94,3	Volcanic + Terrigenous Mud
239	4°12′ S	129°20′24″E	4446	3,2	97,5	″ + ″ ″
242	4°30′ S	129°20′ E	4237	0,4	81,5	″ + ″ ″
245	4°16′30″S	130°15′48″E	4956	12,8	73,2	″ + ″ ″
246	4°38′ S	130°42′ E	5684	0	96,1	Terrigenous Mud
247	4°41′36″S	131°19′ E	4239	0	95,4	″ ″
253	5°48′12″S	132°13′ E	304	17,0	91,2	″ ″
254	5°40′ S	132°26′ E	310	81,4	44,8	Globigerina Ooze
256	5°26′36″S	132°32′ E	397	70,3	91,8	″ ″
262	5°53′48″S	132°48′48″E	560	53,8	76,3	″ ″
264	6° 8′18″S	132°57′48″E	2655	17,8	87,6	Terrigenous Mud
265	6° 3′48″S	132°52′48″E	3026	30,4	93,9	Globigerina Ooze
267	5°54′ S	132°56′42″E	984	53,4	61,9	″ ″
269	5°49′12″S	133°21′42″E	2731	15,3	99,2	Terrigenous Mud
270	5°47′ S	133°39′ E	3565	7,0	99,2	″ ″
271	5°46′42″S	134° 0′ E	1788	16,9	98,3	″ ″
275	4°52′30″S	128°37′ E	4914	0	95,9	″ ″
286	8°50′12″S	127° 2′12″E	883	26,1	85,6	″ ″
289	9° 0′18″S	126°24′30″E	112	41,7	40,2	Shallow Water Deposit
291	9°10′18″S	125°55′ 6″E	421	7,2	99,6	Terrigenous Mud
295	10°35′36″S	124°11′42″E	2050	18,8	99,6	″ ″
297	10°39′ S	123°40′ E	520	29,3	87,8	″ ″
312	8°19′ S	117°41′ E	274	3,6	71,5	Volcanic Mud
314	7°36′ S	117°30′48″E	694	19,7	79,4	″ ″
316	7°19′24″S	116°49′30″E	538	6,5	86,1	″ ″
319	6°16′30″S	114°37′ E	82	30,4	88,9	Terrigenous Mud

CHAPTER IV

RESULTS OF THE MICROSCOPIC EXAMINATION OF THE SAMPLES FROM THE SNELLIUS-EXPEDITION

The results of the mineralogical examination of the samples collected by the Snellius-expedition will now be dealt with, arranged according to the various types of sediment; the mechanical analyses will be discussed at the same time, type by type, as they can be most effectively used in this way.

It is of little use to state that two samples have the same mechanical analysis if it is not also certain that the derivation of the two samples is identical. The latter can be ascertained from the mineralogical composition of the samples.

An illustration of this is given by the mechanical analyses of the Volcanic Mud 77 and the Globigerina Ooze 269 which display the same type. In sample 77 the peaks in the fractions 500—200 μ and 50—20 μ indicate sandy volcanic material and volcanic ash respectively; in the Globigerina Ooze these peaks are due to deposits of pelagic foraminifera with a predominating measurement of 500—200 μ and of many terrigenous components of 50—20 μ respectively. Thus except in mechanical composition these sediments have nothing in common. Another case is the Volcanic Mud 172 and the Terrigenous Mud 280 F which have the same mechanical composition. The first is an aeolian deposit of volcanic ash, the second a terrigenous sediment formed close to the coast. In neither case does the resemblance in mechanical structure justify any conclusions. As in soil science a detached mechanical analysis is not a determining factor in a research, neither is it for deep-sea sediments; at the same time it is a valuable help in the research as to the formation and distribution of similar sediments, as will be seen in the discussion of the mechanical analyses according to type.

The *röntgenographic examination* of 7 typical samples yielded results which will be made use of in the discussion of the sediments; the research is further commented upon in Chap. VI.

It showed that the clay casts formed in the cavities of foraminifera and which did not collapse in the preliminary treatment used for the mechanical analysis, prove to have the same composition as the clay fractions of the same sample. Von Gümbel's suggestion (63) that these clay casts were gradually formed by clay deposits in the dead foraminifera that had sunk to the bottom, is supported by this fact.

The röntgenographic research yields the important result of demonstrating that the clay fractions of Terrigenous Muds and of Globigerina Oozes, as well as those of mixed Volcanic and Terrigenous Deposits, are always of terrigenous origin and that in the specially examined areas of the Banda sea, Ceram sea and Arafoera sea there is a great similarity. Even the small amount of clay found in an aeolian deposit of Tambora ash (167) proved to be not free from terrigenous admixture. This justifies the conclusion that the sediments all correspond in the possession of very fine terrigenous detritus in the clay fractions. These fine terrigenous components differ in amount in the various types of sediment. The amount is small in the Volcanic Muds, in some Coral Muds and in the typical Globigerina Oozes. Generally speaking it is greatest in the Terrigenous Muds, while it may also be high in the mixed Volcanic and Terrigenous Muds as well as in the Globigerina Oozes. The demarcation between Terrigenous Mud and Globigerina Ooze is not other than a gradual increase of the calcium carbonate content (> 30%) with an increasing content of pelagic foraminifera. Thus independantly of the type of sediment, the mechanical analysis of deep-sea sediments, as far as the clay fractions are concerned, gives an indication of the admixture of terrigenous components,

TABLE 2. List of stations of the Snellius-Expedition (by P. H. Kuenen)

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
Indian Ocean	21	4700		< 1°		500	Sig.	48		10—04
" "	23	4800		< 1°		500	Pr. 2	20		10—08
W. of Sumatra	24	4750		< 1°		500	Pr. 3	38		20—08
Java Sea	25	60		< 1°		60	Pr. 2	35		10—88
" "	26	80		< 1°		40	Pr. 3	43		15—83
" "	27	60		< 1°		100	Snap.	small		blue-grey
" "	28	70		< 1°		100	Snap.	large		10—00
Makassar Str.	29	700		2°		160	Pr. 2	30		15—00
" "	30	1850		< 1°		180	Pr. 3 In.	50		15—96
" "	31	1950		< 1°		140	Pr. 2	32		15—00
" "	32	650		< 1°		70	Pr. 2	—		
" "							Snap.	—		
" "	33	2000		< 1°		70	Pr. 3	30	B 0—6	15—00
									A 15—20	28—00
" "	34	1550	< 1°	20°	17°	50	Pr. 2	87		15—00
" "	35	2100		< 1°		30	Pr. 2 In.	78		15—00
Bay of Mamoedjoe	35b	20				1	Snap.	large		28—08
Makassar Str.	36	1250	4°		5°—10°	5	Pr. 3 In.	—		
" "	37	60		< 1°		30	Snap.	large		15—00
" "	38	1400		5°		50	Pr. 3 In.	79		15—00
" "	39	2300		< 1°		100	Pr. 2	12		15—00
" "	39a	2250		< 1°		100	Pr. 2 In.	24		15—00
" "	40	1150	15°	15°	15°	10	Pr. 2 In.	35		28—00
" "	41	2450		< 1°		70	Pr. 2 In.	38		15—00
" "	42	700	18°	18°	18°	50	Pr. 2 In.	1		
Celebes Sea	43	2150	< 1°	3°	< 1°	50	Pr. 2 In.	28		15—00
" "	44	400		< 1°		60	Snap.	large		greenish
" "	45	1000	15°			80	Pr. 3 In.	—		
		1100				80	Pr. 3 In.	37		15—00
" "	46	2050				80	Pr. 2 In.	few g.		grey-green
" "	47	5200	< 1°	3°	< 1°	160	Pr. 2 In.	68		15—96
" "	48	5500		< 1°		140	Pr. 2 In.	48		15—00
" "	49	3100	< 1°, 4°			60	Pr. 3 In.	trace		blue-green
" "	50	1750	< 1°	3°		20	Pr. 2	34		15—04
" "	51	400	8°	6°	7°	3	Snap.	large		
" "	52	5050		< 1°		250	Pr. 2	48		21—00
" "	53	5000		0°		100	Pr. 2	22		21—00
" "	54	3950		± 4°		30	Pr. 2	10		dark
" "	55	1050	< 1°	< 1°	11°	4	Pr. 3	8		dark
" "	56	5050		< 1°		220	Pr. 2	48		14—04
" "	57	4750		< 1°		110	Pr. 2	—		
							Pr. 3	—		
" "	58	2750	7°	7°	7°	30	Pr. 3	50		21—00
Basilan Str.	59	550	3°			30	Snap.	large		26—00
" "	60	90		< 1°		5	Snap.	fair		
" "	61	80		< 1°		5	Snap.	—		
" "	62	450	8°	8°	8°	30	Snap.	—		
Sulu Sea	63	3050	< 1°	?	4°	50	Pr. 3	trace		6—04
" "	64	4350		small		110	Pr. 3	61		
" "	65	3950		small		150	Pr. 3	61		6—04
" "	66	4500				70	Sig.	35		14—04
		4600					Pr. 3	48		14—04
" "	67	2000		1°		30	Pr. 2	50		14—02
N. of Sibutu	68	250		slope		20	Snap.	—		
" " "	69	350		< 1°		20	Pr. 2	small		
Sibutu passage	70	130		small		5	Pr. 2	—		
Celebes Sea	73	1300	10°			30	Pr. 3	54		14—02
" "	74	2700		< 1°		60	Pr. 3	—		
" "	75	4800		< 1°		190	Pr. 2	54		21—96
" "	76	5600		< 1°		140	Sig.	50		dark-grey
" "	77	2800		< 1°		40	Pr. 2	44		15—00
Biaro Str.	78	1500	2°, 2°			20	Snap.	small		yellow-grey
Molukken passage	79	2650		small		60	Pr. 2	35		15—00
Batjan trough	80	4600	3°			70	Sig.	40		21—00

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
11,8	55,5			Globigerina Ooze	0—3 cm = 14—08. Inv. part: 0—40 cm.
10,2	10,9			Terrigenous Mud	Colour: gradual transition 20—08 → 20—04 → 10—04 → 6—04.
4,2	21,5			" "	
5,7	20,5			" "	
5,2	21,2			" "	
		0,15			
8,1	34,3	0,22		Terrigenous Mud	Upper part brown.
9,5	57,9			Globigerina Ooze	
8,7	17,6			Terrigenous Mud	0—2 cm = 28—13.
15,6	14,8			Terrigenous + Volcanic Mud	0—2 cm = 28—13.
					Jaws not closed.
					Not closed.
	2,9			Terrigenous Mud	0—2 cm = 27—04; Stratified, see description.
	2,8				
3,9	39,3			Globigerina Ooze	0—2 cm = 14—08. Inv. part.: 37—87 cm.
9,4	15,8			Terrigenous Mud	Inv. part: 38—78 cm
	trace			" "	
					Jaws not closed.
8,2	6,7	0,27		Terrigenous Mud	Double determination.
7,9	5,1				
7,0	9,7			" "	0—2 cm = 27—13. Inv. part: 0—5 cm.
10,0	5,1			Terrigenous + Volcanic Mud	Colour: gradual transition from 21—00 to 15—00. Distance to station 39a about 3 km.
6,7	5,0			" + " "	Colour: gradual transition from 27—08—15—00—21—00 15—00. Distance to station 39 about 3 km.
9,1	1,4			" + " "	Colour: gradual transition from 20—04 to 28—00.
3,2	3,6			" + " "	Stratified: see description of sample.
				Coarse	Dented: Pebbles with crust of manganese, and Foraminifera.
14,8	25,2			Terrigenous Mud	0—3 cm = 14—04.
	5,6	0,02		" "	
5,7	38,3			Coral Mud	0—1 cm = 14—04. Jaws not closed.
				Coarse + fine	Dented. Pebbles in mud.
4,9	1,8			Terrigenous Mud	0—2 cm = 26—08, then more greenish than lower end.
6,0	23,5			Terrigenous + Volcanic Mud	0—1 cm = brown, gradual transition from 15—04 to 15—00. Distance to station 76 about 1 km.
					Jaws not closed.
5,1	13,4			Terrigenous Mud	0—2 cm = 14—04. Slight indication of stratification.
				Coral Sand	Coarse.
5,4	0,5			Volcanic Mud	0—30 cm = 19—08. Inv. part: 18—48 cm.
	small			" "	0—2 cm = dark brown.
5,1	2,4			" "	
4,5	24,2			" "	Upper part soft, remainder sandy. Inv. part: both.
5,5	1,0			Terrigenous + Volcanic Mud	Colour: 0—9 cm = 26—08; 9—11 cm = 19—04; 11—12 cm = black; 12—15 cm = 19—04; 15—39 cm = 14—04; 39—48 cm = 15—04. Inv. part: whole length.
					Wire broken.
					Jaws not closed.
4,3	20,1	0,07		Terrigenous + Volcanic Mud	Colour: gradual transition from 20—00 to 21—00.
				Coral Sand and Mud	
				Coral Sand	
					Wire broken.
					Not closed.
				Mud	Jaws not closed, much $CaCO_3$.
5,3	38,3			Globigerina Ooze	About 10 indistinct layers. Colours varying between 6—04 and 9—04. Inv. part: 0—40 cm.
13,1	49,0	0,07		" "	Colour: gradual transition from 9—04 to 6—04.
4,3	43,9	0,11		Globigerina Ooze	Upper part less firm. Inv. part: both.
2,7	63,3			Coral Mud	
					Not closed.
				Coarse	Dented. A few pebbles in jaws.
				Hard bottom	Dented. Jaws not closed.
2,0	77,6			Globigerina Ooze + Coral Mud	
					Jaws not closed.
10,9	1,8			Terrigenous + Volcanic Mud	0—11 cm = 14—08.
15,3	1,3			" + " "	0—2 cm = brown. Distance to station 48 about 1 km.
4,2	16,2			Volcanic Mud	0—2 cm = 20—08.
				Fine Volcanic Sand	
3,3	18,1			Volcanic Mud	0—2 cm = 20—08.
16,6	2,1	0,085	1,36	Terrigenous Mud	

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuenen,

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
N. of Batjan	81	1700	2°	2°	2°	30	Pr. 2	small		
" " "	82	1000		< 1°		30	Pr. 2	28		20—00
E. of Batjan	83	400	6°	6°		10	Snap.	small		
" " "	84	1550	1°	1°	1°	60	Pr. 2	7		yellow
" " "	85	700	< 1°	< 1°	< 1°	70	Snap.	large		6—04
" " "	86	350	< 1°	< 1°		50	Snap.	small		
Ceram trough	87	500	< 1°			5	Snap.	small		
" "	88	550	< 1°			30	Snap.	large		15—00
" "	89	1450	1°	1°	1°	60	Pr. 2	26		15—00
" "	90	1750	3°	3°	3°	80	Pr. 3	—		
" "	91	250		< 1°		70	Snap.	large		15—02
" "										
" "	92	650		< 1°		20	Snap.	large		20—00
" "	93	1100	5°		6°	50	Pr. 2	32		20—00
" "	94	750	4°		1°	70	Pr. 2	30		15—00
" "	95	1850	3°		3°	20	Pr. 3	30		15—00
" "	96	850	9°, 7°			10	Pr. 3	26		20—00
Aroe basin	97	2350		< 1°		60	Pr. 2	31		15—00
" "	98	550	< 1°		7°	40	Snap.	trace		
" "	99	1900			< 1°	50	Pr. 2	small		
" "	100	3600			< 1°	50	Pr. 3	28		15—00
" "	101	2200			< 1°	20	Pr. 2	36		15—00
" "	102	350	18°	18°	18°	2	Snap.	—		
							Snap.	fair		
" "	103	600	12°	2°		50	Snap.	large		27—00
" "										
" "	104	3350		< 1°		80	Sig.	62		dark green
E. of Tenimber	105	950		< 1°		60	Pr. 2 In.	48	upper	14—02
									lower	15—00
" " "	106	750		< 1°		80	Pr. 3	42	B upper	14—02
									A lower	21—96
" " "	107	400		< 1°		100	Snap.	large		26—02
" " "	108	600		< 1°		70	Pr. 2 In.	40		15—00
" " "	109	1500	0°	7°	7°	40	Pr. 2 In.	62		15—00
" " "	110	250	< 1°, 11°			10	Pr. 3	34		14—02
S. of Tenimber	111	550		< 1°		80	Pr. 3	40		20—00
" " "	112	1550	< 1°	2°	4°	50	Pr. 3 In.	68		10—00
Timour trough	113	700	< 1°	> 1°	< 1°	30	Pr. 3 In.	—		
" "	114	1500		< 1°		20	Pr. 3 In.	64		grey
" "	115	2100	11°		5°	80	Pr. 3 In.	77		15—00
" "	116	1850	1°	1°	1°	100	Pr. 2 In.	24		10—00
" "	117	600		1°		140	Snap.	large		15—00
" "	118	2900	2°	2°	2°	110	Pr. 2 In.	34		15—02
" "	119	600	3°, 4°			10	Snap.	large		21—02
" "	120	2050	< 1°	< 1°	5°	60	Pr. 2 In.	41		00—02
" "	121	2300	3°	3°	3°	90	Pr. 2 In.	52		15—00
" "	122	1150	2°	2°	2°	120	Pr. 2 In.	35		10—00
" "	123	450		< 1°		150	Snap.	large		20—00
" "	124L	400		< 1°		160	Pr. 2 In.	54		14—00
							Kue, gl.	75		14—00
" "	125	2600		< 1°		50	Pr. 2 In.	41		15—04
" "	126	400	6°, 3°			20	Snap.	large		21—02
" "	127	2350		< 1°		60	Pr. 3 In.	—		
" "	128	1450	1°	1°	1°	80	Pr. 2 In.	23		grey-green
							Kue	102		grey-green
" "	129	400	2°			130	Pr. 2 In.	54		10—02
S. of Roti	130	1850				50	Pr. 2	—		
S.W. of Roti	131	2900				130	Pr. 2	34		10—00
S. of Soemba	132	1300		small		70	Pr. 2	—		
Sawoe Str.	133	500				10	Snap.	fair		
" "	134	950		small		40	Snap.	—		
" "	135	1150		small		60	Snap.	—		
" "	135a	1150				50	Anchor	large		

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
				Coarse	Angular pebble, with film of manganese, and sand.
7,0	35,9			Globigerina Ooze	Colour: gradual transition from 26—02 to 20—00.
				Coarse	Rounded pebbles with Bryozoa etc. attached.
				Globigerina Ooze	Hard, coarse, contains a pebble and fair amount of Globigerina.
		0,04		" "	
				" "	
9,3	35,2			" "	
3,1	55,7	0,07		" "	
4,8	16,7			Terrigenous Mud	Upper end darker.
					Jaws not closed, sample lost above water.
3,6	33,3	0,08		Globigerina Ooze	Double determination.
5,8	34,5				
8,3	55,2	0,17		" "	
3,6	48,2			" "	
3,0	55,6			" "	Jaws not closed, sample partly lost.
5,7	18,3			Terrigenous Mud	Upper part darker.
4,8	35,1			" "	
4,3	20,1			" "	0—½ cm = dark brown.
				" "	Not closed.
				Globigerina Ooze	Jaws not closed.
7,9	13,5			Terrigenous Mud	0—½ cm = dark brown.
6,9	28,6			" "	0—½ cm = dark brown.
					Not closed.
4,4	74,8	0,05	0,53	Terrigenous Mud	Double determination. For $CaCO_3$ see description of sample.
4,1	52,2				
9,2	33,7	0,15		Globigerina Ooze	Double determination.
9,6	28,9				
6,4	8,6			Terrigenous Mud	
					Sandy, gradual transition.
5,6	53,4			Globigerina Ooze	Less sandy.
5,8	68,9			" "	Sandy.
8,3	6,6			Terrigenous Mud	Firm and tough.
6,8	37,5	0,36		Globigerina Ooze	
9,3	32,4			" "	Colour: gradual transition from 20—00 to 15—00.
7,1	31,3			" "	0—½ cm = brown. Gradual transition from 20—00 to 15—00.
4,0	64,9			" "	
7,5	28,8			Terrigenous Mud	Jaws not closed, about 20 cm of sample lost.
18,6	33,7			Globigerina Ooze	0—2 cm = brown. Inv. part 50—68 cm.
				Hard bottom	Dented, glass tube broken.
12,0	29,8			Terrigenous Mud	0—2 cm = brown.
5,3	31,1			Globigerina Ooze	0—½ cm = brown, gradual transition from 15—02 to 15—00.
5,5	44,2			" "	Jaws not closed, sample partly lost.
4,7	56,4	0,14	1,70	" "	Double determination.
6,3	52,6				
5,6	34,4			" "	0—5 cm = brownish.
5,8	17,0	0,06	1,07	Terrigenous Mud	Very tough.
4,1	27,1			" "	0—2 cm = brownish, gradual transition from 00—02 to 00—98.
5,1	27,5			" "	0—3 cm = 14—06.
4,3	46,1			Globigerina Ooze	
9,2	53,8			" "	Double determination.
7,6	54,3				
2,7	76,6			Coral Mud	Upper ends somewhat lighter. Distance between the two soundings small.
2,7	80,1				Inv. part: 45—75 cm.
5,2	32,2			Terrigenous Mud	0—1 cm = yellowish brown.
4,2	27,2	0,11	1,14	" "	
					Jaws not closed, sample was about 50 cm, before it was lost.
					0—¼ cm = brown.
11,7	41,7			Globigerina Ooze	0—½ cm = brown. Inv. part 0—10 cm.
2,6	84,0			Coral Mud	Upper end brownish.
				Sand	Trace in jaws.
6,3	26,3			Terrigenous Mud	0—1 cm = brown.
					Soft bottom, no sample procured.
9,9	50,8	0,065	0,70	Globigerina Ooze	
					Closed, but no sample.
					Closed, but no sample.
				Coarse	

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuenen,

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
Sawoe Str.	136	400				20	Snap.	large		
Dao Str.	137	450		slope		40	Snap.	large		
” ”	138	950		small		50	Snap.	large		20—04
” ”	139	400		slope		10	Snap.	small		
” ”	140	1100		small		30	Snap.	—		
” ”	141	1500		slope		50	Pr. 2	63		15—00
Sawoe Str.	142	1850		slope		50	Pr. 3	44		20—02
S. of Soemba	143	1650	4°	4°	4°	30	Pr. 3	62		15—00
Indian Ocean	144	2800	4°	4°	4°	100	Pr. 2	26		15—00
” ”	145	5700		< 1°		140	Sig.	62		21—02
” ”	146	5350		< 1°		290	Sig.	50		21—02
” ”	147	3700		< 1°		120	Pr. 3	—		
Soemba Str.	148	1200		< 1°		30	Pr. 3	44		21—00
Flores Sea	149	1400		slope		30	Pr. 2	—		
Sape Str.	150	200		slope		10	Snap.	trace		
Soemba Str.	151	900				20	Snap.	large		27—04
Sawoe Sea	152	1950				40	Pr. 2	32		21—02
” ”	153	2950				90	Pr. 2	28		20—02
” ”	154	2000		small		60	Pr. 2	29		15—00
” ”	155	3350		small		90	Pr. 2	35		15—02
S. of Roti	156	1850		small		40	Pr. 2	1		
							Snap.	—		
Sawoe Sea	157	450	2°	2°	2°	5	Snap.	—		
							Snap.	small		
” ”	158	1950	5°		8°	20	Pr. 2	33		15—04
” ”	159	3250		1°		60	Pr. 2	33		21—04
” ”	160	3200		< 1°		20	Pr. 2	21		21—02
E. of Alor	161	1000				20	Snap.	trace		
” ” ”	162*	2050		small		20	Pr. 2	small		
Sawoe Sea	163	3350				40	Pr. 2	20		dark grey
Banda Sea	164	3850		< 1°		80	Pr. 2	—		
Flores Sea	165	450		< 1°		120	Pr. 2	trace		
” ”	166	2000			5°	90	Pr. 2	24		26—02
” ”	167	3500		< 1°		40	Pr. 3a	29	upper lower	
” ”	168	2600		< 1°		10	Pr. 2	—		
” ”	169	600	15°, 22°			2	Snap.	large		
” ”	170	1400		< 1°		80	Snap.	large		
Madoera Str.	171*	90				20	Pr. 2a	72		blue-green
Bali trough	172	700				60	Pr. 2	—		
		750					Pr. 2 In.	22		15—00
” ”	173	1500	< 1°	3°	3°	40	Pr. 3a	15		blue-grey
Flores Sea	174	1250	3°	3°	3°	30	Pr. 2 In.	30		15—00
” ”	175	2750	8°, < 1°			40	Pr. 2 In.	25		15—00
” ”	176	650	< 1°	< 1°	< 1°	80	Pr. 3a	trace		
” ”	177	1600	2°	2°	2°	90	Snap.	trace		
” ”	178	2700	1°	1°	1°	90	Pr. 3a	67		15—02
” ”	179	4000	1°	1°	1°	90	Pr. 3a	72		27—02
” ”	180	5100	< 1°	< 1°	< 1°	60	Pr. 2a In.	42		28—04
” ”	181	2800	12°		6°	20	Pr. 3a	55		15—00
” ”	182	900	14°	17°	18°	5	Snap.	large		26—00
” ”	182L	80	37°		2°	50	Snap.	fair		
N. of Paternoster	183	550	< 1°	< 1°	< 1°	130	Pr. 2a In.	trace		black-brown
N. of Postiljon	184	400				160	Pr. 2a In.	trace		dark-brown
S. of Makassar	185	650	< 1°	< 1°	< 1°	30	Pr. 2a In.	48		14—02
Saleyer trough	186	1400	13°, 15°		> 10°	2	Snap.	large		20—02
” ”	187	3100		< 1°		20	Pr. 2a In.	74		10—00
Gulf of Bone	188	1000	4°, 6°			20	Pr. 2a In.	34		15—02
” ” ”	189	1850	< 1°	< 1°	12°	50	Pr. 2a In.	44	I 0—11	21—02
									II 11—12	15—00
									III 12—23	21—02
									IV 23—30	15—00

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
3,9	80,0	0,035	0,33	Globigerina Ooze	
8,5	76,8	0,065	0,62	" "	
4,7	61,4			" "	
				Coral Sand	Coarse and finer calcareous sand: Balanus, Corals, Lamellibranchia and Foraminifera.
					Closed, but no sample.
11,7	21,0			Terrigenous Mud	Very soft. Inv. part: 0—20 cm.
5,2	18,6			Terrigenous Mud	Colour: gradual transition from 20—06 to 20—02.
4,1	35,5			Globigerina Ooze	0—1 cm = brown. Inv. part: 22—62 cm.
5,2	29,7			Terrigenous Mud	0—1 cm = 27—08.
6,4	4,3			" "	Upper end colour: 15—13.
6,0	1,0			Red Mud	0—20 cm gradual transition from 14—08 to 21—02.
					Jaws not closed.
2,6	61,2			Globigerina Ooze	
				Hard bottom?	Jaws closed, but no sample.
				Sand	
4,7	17,7			Volcanic Mud	
2,9	8,6			Terrigenous + Volcanic Mud	Upper end brownish.
5,2	10,9			Terrigenous Mud	Colour: gradual transition from 20—04 to 20—02.
5,7	16,6			" "	Upper end brownish.
3,7	9,9			" "	0—1 cm = dark brown. Distance to station 379 about 4 km.
				Hard bottom	Yellow marley limestone punched out of hard bottom, covered with 1 mm of manganese, and a few mm of loosely cemented Foraminifera and sand.
					Not closed.
				Shallow Water Deposit	Gastropoda, Pteropoda, Lamellibranchia, Bryozoa, Foraminifera, with terrigenous sand and mud.
4,2	13,9			Terrigenous Mud	Upper end more brownish.
3,9	4,9			" "	0—1 cm = brown.
5,5	9,9			Terrigenous + Volcanic Mud	0—1 cm = dark brown.
				Terrigenous Mud	
				Coarse, with few sand	Angular lava pebble, fragments of shells, and a few Foraminifera. Film of manganese.
8,6	6,2			Terrigenous Mud	
					Closed, no sample, but not dented.
				Coral Mud	
6,1	33,6			Terrigenous + Volcanic Mud	
5,9	5,1	0,050	0,66	Volcanic Mud	Finer grain towards lower end.
		0,030	0,40		
					Not dented.
5,5	7,6	0,08	0,98	Volcanic Mud	
6,9	8,1	0,045	0,46	" "	
				Terrigenous + Volcanic Mud	
					Wire broken.
4,9	9,6			Volcanic Mud	
7,7	7,1			" "	
2,7	32,2			Globigerina Ooze	
6,3	22,7			Terrigenous + Volcanic Mud	0—2 cm = brownish.
				Clay + Sand	
				" + "	
5,9	31,1			Terrigenous + Volcanic Mud	Upper end brown. Inv. part: 32—67 cm.
6,9	12,3			" + " "	Colour: gradual transition from 15—02 to 27—02. Inv. part: 0—35 cm.
2,2	5,2			Volcanic Mud	0—½ cm = brown. Colour: gradual transition from 27—04 to 28—04.
5,4	21,7			Terrigenous + Volcanic Mud	0—2 cm = dark brown.
5,0	37,7	0,20		Terrigenous Mud	
4,2	89,2			Coral Sand	
				Volcanic Mud	
				" "	
6,7	66,6	0,19		Globigerina Ooze	
5,0	52,6	0,14		Terrigenous Mud	
11,3	45,9			" "	0—½ cm = dark brown. 15—20 cm = coarse layer with Foraminifera.
6,8	70,1			Globigerina Ooze	
7,7	31,1			" "	Thin brown upper end. Distance between the two soundings about 2 km.
6,2	43,1			" "	
7,8	14,4			Terrigenous Mud	
6,4	48,5			Globigerina Ooze	

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuenen,

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
Gulf of Bone	189	1850							V 30—35	21—02
									35—40	15—00
									40—45	21—02
							Kue	168	A 0— 6	15—02
									B 68—74	
									C 162—168	28—02
Gulf of Bone	190	1400	3°, 6°			10	Pr. 2a In.	61		20—02
" " "	191	2000		1°		50	Pr. 2a In.	26	A upper	20—04
									B lower	21—02
" " "	192	2550	< 1°		2°	70	Pr. 2a In.	63		15—00
S. of Boeton	193	1700	4°		< 1°	100	Pr. 2a In.	64		15—02
							Kue	174	E 10—15	15—00
									D 15—20	
									C 70—75	
									B 100—105	
									A 170—174	20—02
N. of Flores	194	2700	2°		2°	60	Pr. 2a In.	55	B 0—28	28—88
									A 28—55	27—10
Flores Sea	195	500	16°			1	Snap.	fair		
" "	195L	1150		slope		2	Snap.	fair		
" "	196	2200	17°			5	Snap.	—		
" "	197	5100	2°	2°	2°	30	Pr. 2a In.	50		21—00
" "	198	2800	16°, 17°			20	Pr. 2a In.	—		
S. of Saleyer	199	800	7°	12°	9°	20	Pr. 3a	few c.m.		
Gulf of Bone	200	1100	9°			50	Snap.	fair		
S. of Toekangbesi	201	2950	14°			20, 40	Pr. 3a	25		10—00
Banda Sea	202	3900	< 1°	< 1°	< 1°	90	Sig.	60		21—02
N. of Flores	203	3500	< 1°	< 1°	< 1°	30	Pr. 3a	44		dark
" " "	204	1500	15°, 6°			10	Snap.	small		
Banda Sea	205	3950	14°	< 1°	< 1°	110	Sig.	45		15—00
S. of Toekangbesi	206	1250				5	Snap.	fair		
N. of Tenimber	207	1200				40	Pr. 2a. In.	trace		
Banda Sea	208	3500		slope		80	Pr. 2a. In.	44		15—00
" "	209	4200	6°	7°	±10°	120	Pr. 2a. In.	64		21—00
" "	210	4900	3°	3°	3°	20	Pr. 3a In.	57		
" "	211	2050	22°		6°	5	Snap.	fair		
" "	212	5000	1°	1°	1°	160	Pr. 3a In.	80		21—02
" "	213	1150	4°, 25°			10	Pr. 2a In.	small		
" "	214	3000	2°		1°	40	Pr. 2a In.	72		10—00
, "	215	4750	2°	2°	2°	110	Pr. 2a In.	80	30—70	21—00
									70—80	
, "	216	3050	10°	< 1°	< 1°	30	Pr. 2a In.	54		15—00
" "	217*	1400	15°			20	Snap.	small		
" "	218	4400	< 1°	< 1°	5°	100	Pr. 3a In.	79	0—30	21—00
Sanana Str.	219	1200				10	Snap.	—	70—79	
" "	220	2600				40	Snap.	small		10—04
" "	221*	3650		small		20	Pr. 2a In.	6		
" "	222	1200				2	Snap.	fair		
Lifamatola Str.	223	500				10	Snap.	trace		
" "	224	1100				40	Snap.	—		
" "	225*	1950				60	Snap.	small		
" "	226	500	3°	3°		20	Snap.	—		
Batjan trough	227	2950	< 1°	< 1°	11°	50	Pr. 2a In.	67		15—02
Lifamatola Str.	228	2650		slope		40	Pr. 2a In.	15		grey
Boeroe trough	229	5150	7°	7°	7°	60	Pr. 3a	65		27—00
Manipa Str.	230	1400		small		20	Snap.	small		
Banda Sea	231	1100		slope		20	Snap.	fair		grey
" "	232	4600		< 1°		50	Pr. 3a	28		21—00

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
7,0	22,7			Terrigenous Mud	
6,6	46,2	0,15	1,70		Double determination.
5,8	48,2			Globigerina Ooze	
8,1	45,9			" "	Colour: gradual transition.
7,7	22,2	0,125	1,66	Terrigenous Mud	Double determination.
6,9	23,4				
5,2	29,6			" "	Inv. part: 0—35 cm.
5,3	13,0			" "	0—½ cm = brown.
2,7	8,9			" "	
4,8	25,3			" "	Colour: irregular variation between 15—00 and 21—00.
5,2	53,9			Globigerina Ooze	0—2 cm = brown. Gradual transition from 10—00 to 15—02. Inv. part: 0—40 cm.
10,8	52,6			" "	0—2 cm = brown. Colour: gradual transition. Distance between the two soundings about 0,2 km.
5,9	52,6			" "	
6,4	57,6			" "	
4,6	53,9			" "	
7,0	47,4			" "	
6,6	18,6			Terrigenous + Volcanic Mud	Sharp margin.
11,8	2,8			Red Clay	
				Coarse	One piece of lava.
				Coarse	Lapilli and shells.
6,2	5,9			Terrigenous + Volcanic Mud	Inv. part: 0—20 cm.
					Jaws not properly closed, sample lost.
				Coral Sand	Corals, Balanus, Lamellibranchia, Foraminifera etc.; coating of manganese.
5,6	72,9			Globigerina Ooze	Contains some pebbles.
5,6	46,2			" "	Inv. part: 15—25 cm.
9,7	5,3			Terrigenous + Volcanic Mud	Colour: gradual transition from 15—02 to 21—02. Inv. part: 0—30 cm.
11,2	8,0	0,07	0,77	Volcanic Mud	Inv. part: 0—20 cm. Organic matter averaged upper and lower end.
				" "	Fair amount of $CaCO_3$.
10,2	30,5			Terrigenous + Volcanic Mud	
5,0	91,7			Coral Sand + Globigerina Ooze	
				Sand	
9,8	24,9	0,075	1,03	Terrigenous Mud	Colour 0—20 cm = 14—04; 20—44 cm = 15—00.
10,7	2,2	0,12	1,28	" "	0—5 cm = dark brown. Inv. part: 0—35 cm. Gradual variation from 20—02 to 21—00.
2,7	18,5	0,04	0,46	Terrigenous Mud	Jaws not closed, sample partly lost.
				Coarse	Fine, rounded gravel and some fragments of shells.
8,6	5,1	0,13	1,30	Terrigenous Mud	0—4 cm = brown. Gradual transition from 15—02 to 21—02. Inv. part: 0—35 cm.
				Globigerina Ooze	Calcareous sand, principally Foraminifera.
11,1	29,0			Terrigenous Mud	Colour: gradual transition from 14—04 to 10—00. Inv. part: 0—35 cm.
7,3	7,6	0,11	1,14	" "	0—20 cm = 20—08.
12,1	5,5			" "	
8,8	32,8	0,13	1,29	" "	
				Coarse	Angular pebbles and sand with some Foraminifera.
8,7	0,7	0,09	1,14	Terrigenous Mud	0—½ cm = brown.
6,4	11,6			" "	
				Terrigenous Mud	
				Terrigenous Sand	Fine, angular gravel (quartz etc.), with trace of sand and lime, some small manganese nodules, and clay.
				Coarse	Sand and pebbles, and some clay.
				Sand	
				Terrigenous Sand	Sand with film of manganese and fair amount of Foraminifera.
10,0	24,1	0,10	1,10	Terrigenous Mud	0—2 cm = brown. Inv. part: 37—67 c.m
5,0	30,1			" "	Very firm. Inv. part: 0—5 cm.
5,6	0,8	0,23	2,20	" "	
				Coarse	Rounded pebbles of pumice, fragment of shist and of Gastropoda.
8,4	24,0	0,05	0,60	Terrigenous Mud	
10,6	3,8	0,10	1,16	" "	0—½ cm = brown.

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuenen,

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
Banda Sea.	233	1750		< 1°		80	Pr. 2a In.	67		10—00
" "	234	3600	4°, 5°			130	Pr. 3a	trace		
" "	235	5050		< 1°		120	Pr. 2a In.	75	A 0—10	15—02
									B 65—75	21—00
" "	236	3600	1°	1°	1°	50	Pr. 3a In.	65		15—02
" "	237	3150	2°	2°	2°	30	Pr. 3a In.	60		15—00
" "	239*	1250	12°, 9°			160	Snap.	small		
" "	240	3250	3°		< 1°	160	Pr. 3a In.	—		
" "	241	4850		< 1°		90	Pr. 2a In.	80	A 0—40	21—04
									B 40—80	
" "	242	3350		5°		30	Pr. 2a In.	57		10—02
" "	243	1200	15°, 8°			5	Snap.	—		
" "	244	2600	13°	< 1°		90	Pr. 2a In.	trace		
" "	245	4450		< 1°		30	Pr. 2a In.	33	A 5—10	dark
									B 10—15	15—02
" "	246	4400		< 1°		30	Pr. 2a In.	79	A 0—10	15—00
									B 70—79	
" "	247	1550	8°, 10°			5	Snap.	small		
" "	248	2650	4°, 6°			140	Pr. 2a In.	80		10—00
" "	249	4150	< 1°		< 1°	130	Pr. 3a	10		grey
" "	250	1050	14°		3°	80	Snap.	fair		
" "	251	5100	< 1°	< 1°	< 1°	50	Pr. 2a In.	70		15—00
" "	252	1500	18°			5	Snap.	small		
Manipa Str.	253	4050		slope		20	Sig.	trace		
Banda Sea	253L	950		slope		5	Snap.	large		20—02
" "	254	?				60	Pr. 2a In.	—		
Manipa Str.	255	3300		small		20	Pr. 2a In.	66		21—02
" "	256	1250		small		20	Snap.	fair		
Boeroe trough	257	2950				50	Pr. 2a In.	13		10—04
Mindanao trough	260	7950	< 1°	< 1°	< 1°	150	Sig.	59		21—00
" "	261	9850				90	Sig.	22		21—02
" "	262	10050				80	Sig.	54		21—04
" "	263	3750			10°	160	Pr. 2a In.	small		brown
" "	264	9300			4°, 2°	130	Sig.	7		blue-green
" "	265	4950	< 1°	4°	4°	90	Sig.	24		brown
" "	266	2550	11°, 14°			50	Pr. 2a In.	—		
N. of Miangas	267	400	5°			30	Snap.	trace		
" " "	268	750			7°	40	Snap.	trace		
Mindanao trough	269	550	4°			5	Snap.	large		
" "	270	4600	11°	9°	10°	100	Pr. 2a In.	—		
" "	271	7950	< 1°	3°	3°	150	Sig.	14		14—06
" "	272	5300	< 1°	< 1°	< 1°	240	Pr. 2a In.	—		
" "	275	5550			2°, 3°	80	Pr. 3a	trace		
" "	276	4300		< 1°		110	Pr. 3a	70		15—02
N.E. of Kaoe Bay	277	600				10	Snap.	trace		green
Kaoe Bay	278	500				10	Pr. 3a	79		
							Kue	168		
" "	279	500				10	Kue	148		27—02
" "	280L	200				5	Pr. 3a	82		greenish
" "	280	400				5	Pr. 3a	79		greenish
							Kue	128	F 0—30	26—00
									D 98—128	26—00
Morotai trough	283	600			4°	10	Snap.	fair		
" "	284	3700			3°, 5°	40	Pr. 3a	54		
" "	285	2000	< 1°	< 1°	< 1°	70	Pr. 3a	53		
" "	286*	600	11°, 6°			20	Snap.	fair		
" "	287	700	5°		8°	90	Snap.	—		
" "	288	2200	< 1°	< 1°	< 1°	80	Pr. 3a	trace		
Siaoe Str.	289	1600				20	Snap.	fair		

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
7,7	42,6	0,06	0,78	Globigerina Ooze	0—5 cm = yellowish. Inv. part: 0—30 cm.
				Terrigenous Mud	Soft mud between weights, from brown upper layer.
8,9	1,5	0,12	1,32	Terrigenous + Volcanic Mud	0—5 cm = brown. Remainder gradual transition.
6,8	8,5			„ + „ „	
4,4	16,6	0,08	0,86	„ + „ „	0—½ cm = brown.
2,0	22,5	0,06	0,70	Volcanic Mud	0—¼ cm = brown. Lower and more greenish.
				Globigerina Ooze	Calcareous sand, principally Foraminifera and some grains of manganese.
					Not dented.
6,6	3,6	0,11	1,26	Terrigenous + Volcanic Mud	0—20 cm = gradual transition from 27—08 to 20—08.
2,8	11,3			„ + „ „	
2,5	54,3	0,08	0,86	Globigerina Ooze	0—4 cm = brown.
					Wire broken.
				Globigerina Ooze	Jaws not closed.
2,1	0,8			Fine Volcanic Sand	
8,6	4,2			Volcanic Mud	
3,3	2,7	0,12	1,16	„ „	About 4 brown layers of 1—2 cm, divided by brown-grey layers of 8—10 cm. Lower part: 15—00.
4,4	3,5			„ „	
				Terrigenoud Mud	
5,6	48,3	0,065	0,88	Globigerina Ooze	0—4 cm = brown. Inv. part: 0—35 cm.
18,9	13,4	0,085	1,14	Terrigenous + Volcanic Mud	Upper layer brown.
9,5	42,1	0,045	0,50	Globigerina Ooze	Hard, brittle.
6,4	2,4	0,09	0,98	Terrigenous Mud	Inv. part: 0—35 cm.
				Coarse	Rounded gravel (quarts, shist etc.).
				Terrigenous Mud	
4,4	37,1	0,13	1,30	„ „	Double determination.
3,3	34,3				
					Sounding stopped, wire too loose.
5,6	5,8			Terrigenous Mud	0—½ cm = brown. Gradual transition from 26—02 to 21—02. Inv. part: 0—35 cm.
				Coarse	Coarse and fine, angular gravel (mica shist, etc.), with film of manganese.
7,3	1,5			Terrigenous Mud	Firm. Inv. part: 6—13 cm.
9,7	0,6			„ „	Upper layer brown. Gradual transition from 10—04 to 21—00. Distance to station 271 about 4 km.
5,9	6,6			„ „	Colour: 14—04 and 21—02 alternating. Distance to station 262 about 9 km.
5,9	1,6			„ „	Irregular transition from 14—04 to 21—04. Inv. part: 0—30 cm.
				Red Clay	Dented, probably on manganese nodules.
4,4	0,5			Terrigenous Mud	
5,2	1,8			„ „	Inv. part: 10—24 cm.
					Jaws not closed.
				Sand	
				Terrigenous Mud	
3,2	56,7	0,025	0,37	Globigerina Ooze + Coral Mud	
				Hard Bottom	Dented, bottom very irregular.
13,5	0,8			Terrigenous Mud	Firm. Inv. part: 9—14 cm. Distance to station 260 about 4 km.
					Wire broken.
				Terrigenous Mud	Trace in jaws.
6,6	19,8			„ „	0—5 cm = brown.
				Mud and Sand	Not closed, fallen over.
					Colour: see description. Distance between the two soundings about 1 km.
9,5		0,20	4,05	Terrigenous Mud	Colour: see description. Investigated: mixture of whole length.
	12,0	0,17	3,72	„ „	See description of sample for stratification.
		0,18	3,20	„ „	Lower end more sandy. Inv. part: 0—55 cm.
8,5	20,5			„ „	Inv. part: 0—40 cm.
6,2	21,0			„ „	Dark layers at 63, 65, 77, 107 cm.
6,2	14,0			„ „	For distance between soundings in Kaoe Bay see description of station 278.
5,6	62,7	0,05	0,50	Globigerina Ooze	
5,3	9,9	0,11	1,20	Terrigenous + Volcanic Mud	
	42,7	0,045	0,52	Globigerina Ooze	
				„ „	Sand, angular calcareous sand (Foraminifera), and gravel with film of manganese.
					Not closed.
					Hard clay in unclosed jaws.
				Coarse	Coral and pebbles with coating of manganese.

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuener

Position	Station	Depth in m	Slope below	Slope at	Slope above	Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
Sangihe trough	290	1150	8°		2°	20	Snap.	fair		
" "	291	2550		< 1°		50	Pr. 3a	84		15—02
" "	292	2500		< 1°		30	Pr. 3a	53		15—02
N. of Talaud	293	850		slope		10	Snap.	large		
" " "	294	1850				60	Snap.	small		
" " "	295	850				100	Snap.	fair		
Sangihe trough	296	3400	6°			80	Pr. 3a	49		21—94
Kawio Str.	297	2600				30	Pr. 3a	—		
" "	298	800		slope		10	Snap.	small		
" "	299	1500				30	Snap.	fair		
		1400				30	Snap.	small		
" "	300	700				60	Snap.	—		
Celebes Sea	301	5200	< 1°		2°	140	Pr. 3a	77	A 0—10	
									B 67—77	
" "	303	4450	6°	< 1°	< 1°	100	Pr. 2a	53		14—06
" "	305	3550	< 1°	< 1°	< 1°	150	Pr. 2a	51		21—02
" "	309L	5100		< 1°		140	Sig.	40		
N. of Flores	317a	2350				70	Anchor	large		15—02
S.E. of Banda	320	2550	8°	< 1°	< 1°	60	Pr. 3a	41		15—02
Weber deep	321	6600	< 1°	< 1°	< 1°	.100	Pr. 2a In.	—		
" "	322	3350	3°		3°	40	Pr. 2a In.	78		15—00
S.E. of Manowoka	323	550		< 1°		20	Snap.	small		dark brown
Ceram trough	324	2150	< 1°	< 1°	< 1°	50	Pr. 2a In.	59		15—00
" "	325	2000	< 1°		5°	40	Pr. 2a	50		21—02
" "	326*	500	2°			10	Snap.	fair		
" "	327	1450	4°			40	Pr. 3a	57		15—00
" "	328	2950	6°			50	Pr. 2a	48		15—00
" "	330	4450			2°	60	Kue	152	A 0—6	27—00
									B 100—106	
									C 146—152	28—00
Banda Sea	331	5050	< 1°	< 1°	< 1°	130	Kue	187	A 0—6	20—02
									B 80—86	
									C 181—187	21—00
Batjan trough	333	2700	5°	< 1°		100	Pr. 2a	59		15—02
Molukken pass.	334	2700	< 1°	< 1°	7°	60	Pr. 2a	64		15—00
" "	335	2100	< 1°	< 1°	< 1°	140	Pr. 2a	80		10—02
" "	336	2350	< 1°	< 1°	< 1°	120	Pr. 2a	74		10—02
" "	337	3850	< 1°		3°	50	Pr. 3a	14		light brown
" "	338	1800	< 1°		7°	30	Pr. 3a	71		15—00
" "	339	450	2°, 3°			10	Snap.	fair		
" "	340	2500	< 1°	< 1°	1°	30	Pr. 2a	small		
" "	343	1250			7°	80	Pr. 2a	9		9—06
" "	344	2500	3°			100	Pr. 2a	57	B 0—30	
									A 30—57	
" "	345	2750	< 1°		2°	40	Pr. 3a	10	5—10	grey
" "	346*	500	29°, 6°			10	Snap.	small		
" "	347	3050	< 1°	< 1°	< 1°	50	Kue	176	B 0—6	21—00
									C 80—86	
									A 170—176	21—02
Mindanao trough	350	2600			5°	100	Pr. 3a	71		15—00
E. of Halmaheira	351	800	< 1°		10°	50	Snap.	fair		
" " "	352	1050	11°			30	Pr. 2a	small		
Halmaheira trough	353	1900	< 1°	< 1°	< 1°	70	Pr. 3a	59		
" "	354	600	6°, 0°			100	Snap.	—		
E. of Obi	354a	1350	< 1°		3°	80	Pr. 3a	—		
							Anchor	large		blue-green
Ceram trough	355	2050	< 1°		6°	60	Pr. 3a	8		dark green
Weber deep	357	1600	14°, 21°			30	Pr. 3a	—		
" "	358	4450		1°		60	Kue	138	0—45	
" "	359	3550	< 1°	< 1°	< 1°	20	Pr. 3a	trace		dark
" "	360	1100	34°		1°	5	Snap.	large		
" "	361	2650	< 1°	< 1°	< 1°	30	Pr. 3a	62		21—00

type of sediment determined by G. A. Neeb.)

Moisture	CaCO3	Organic		Type of Sediment	Remarks
		Nitro	Carbon		
5,9	44,0	0,03	0,38	Globigerina Ooze	
7,7	15,7	0,09	1,02	Terrigenous Mud	0—3 cm = brown. Inv. part: 0—35 cm.
11,0	19,2	0,09	1,04	" "	0—4 cm = brown.
7,7	21,1	0,05	0,62	" "	
				Marl and Sand	Coating of manganese on marl and sand.
				Coarse	Deep sea coral and angular fragments of lava, with film of manganese.
7,9	0,5	0,07	0,88	Terrigenous Mud	0—3 cm = brown.
				Hard Bottom	Dented.
				Coarse	Fragment of coral with film of manganese, and with sponge adhering.
6,7	34,6	0,01	0,10	Globigerina Ooze	Coarse and sand. Inv. part is sand. Grains of manganese.
				Coarse	Pebbles with coating of manganese.
7,1	trace	0,05	0,64	Terrigenous + Volcanic Mud	Stratification: see description.
9,2	0,3			" + " "	
5,4	12,1	0,10	1,03	" + " "	0—11 cm = brown. Gradual transition from 27—04 to 14—06 to 15—02.
4,9	5,2	0,16	1,74	Terrigenous Mud	
11,7	0,8			" "	
7,3	22,8	0,185	1,94	Terrigenous + Volcanic Mud	
2,1	69,6			Globigerina Ooze	Colour: gradual transition from 10—02 to 15—02.
					Dented.
10,1	9,5	0,14	1,48	Terrigenous Mud	Colour: gradual transition from 15—00 to 20—83. Inv. part: 0—35 cm.
				Marl with concretions	Larg number of small concretions.
17,1	15,6	0,23	2,56	Terrigenous Mud	0—½ cm = dark brown. Gradual transition from 21—02 to 15—00. Inv. part: 0—40 cm.
	15,7	0,27	2,76	" "	
				" Sand	Fine gravel and sand with some Foraminifera and fragments of shells.
3,6	35,1	0,12	1,18	Globigerina Ooze	Inv. part: 0—40 cm.
4,2	33,2	0,15	1,54	" "	Colour: between 15—00 and 15—96.
8,0	3,7	0,29	2,90	Terrigenous Mud	Colour: gradual transition. Stratified: see description of sample.
4,8	12,9			" "	
8,2	9,6	0,24	2,74	" "	Colour between 28—00 and 28—96.
9,6	0,7	0,12	1,36	" "	Colour: gradual transition.
6,1	1,5			" "	
11,9	2,6	0,16	2,58	" "	
5,5	23,0	0,10	1,10	Terrigenous + Volcanic Mud	0—1 cm = brown.
6,5	18,4	0,09	1,16	Terrigenous Mud	Inv. part: 0—35 cm.
5,3	33,7	0,07	0,96	Globigerina Ooze	0—½ cm = brown. Inv. part: 0—40 cm.
6,7	25,0	0,06	0,92	Terrigenous + Volcanic Mud	0—½ cm = brown. Inv. part: 0—35 cm.
11,0	4,9		0,49	" + " "	Lapilli in lower end.
6,1	33,8	0,09	1,04	Globigerina Ooze	Inv. part: 0—35 cm.
				Coarse	Coarse to fine gravel with film of manganese, Bryozoa attached; fragments of shells.
				Coarse	Fragment of friable shale with boring canals, and film of manganese.
13,6	1,3			Terrigenous + Volcanic Mud	Very firm.
2,9	22,9	0,05	0,76	Volcanic Mud	
4,2	23,6			" "	
4,2	3,8	0,01	0,41	" "	0—5 cm = dark sand.
				Coarse	Fragment of coral and sand, with trace of lime.
5,3	11,5	0,11	1,43	Volcanic Mud	Stratification: see description of sample.
5,7	10,5			" "	
5,1	19,3			" "	
6,8	25,9	0,11	1,18	Terrigenous Mud	0—3 cm = brown. Inv. part: 26—71 cm.
				Coral Sand	Coarse calcareous sand, Corals, Pteropoda, Gastropoda, Echinoidea, Foraminifera etc.
				Caorse, Coral	Hard coarse.
	42,6	0,20	2,02	Globigerina Ooze	
	59,2			Globigerina Ooze	
8,9	9,0			Terrigenous Mud	Firm.
				Hard Bottom	Dented.
2,5	2,0	0,05	0,81	Terrigenous + Volcanic Mud	Stratification: see description of sample.
8,6	15,6	0,11	1,36	Terrigenous Mud	
7,0	13,9	0,12	1,34	" "	Inv. part: 0—35 cm.

Table 2. List of stations of the Snellius-Expedition (by P. H. Kuenen,

Position	Station	Depth in m	Slope			Distance to coast in km	Sampler	Amount or length cm	Part.	Colour
			below	at	above					
Weber deep	362	7350	< 1°	< 1°	< 1°	70	Sig.	15		21—02
" "	363	950	8°		< 1°	80	Pr. 3a	12		blue-grey
" "	364	1100	6°		5°	30	Pr. 2a	small		
		1150				40	Snap.	small		
" "	364a	4450				30	Kue	119	I 0—6	21—98
									II 60—66	
									III 113—119	
" "	365	6300	< 1°	< 1°	< 1°	80	Sig.	16		
" "	368	2450	3°		3°	60	Pr. 3a	66		10—02
" "	369	4500	< 1°	< 1°	< 1°	50	Pr. 3a	60		21—04
" "	370	1700	< 1°	< 1°	< 1°	30	Pr. 2a	42		15—00
" "	372	950	5°, 8°			30	Snap.	small		
" "	373	4100	< 1°		3°	70	Pr. 3a	72		
" "	374	2550	13°, 6°			30	Kue	206	A 0—10	grey
									F 10—16	
									C 66—72	
									B 114—120	
									E 120—126	
									D 168—174	
									H 200—206	dark grey
E. of Timor	375	1450	6°		6°	20	Pr. 3a	8		
Wetar trough	376	3300	< 1°	< 1°	< 1°	30	Pr. 2a	50		21—00
" "	377	3400	< 1°	< 1°	< 1°	30	Pr. 3a	60		21—02
Sawoe Sea	379	3300	< 1°	< 1°	< 1°	90	Kue	128		
" "	380*	3350	< 1°	< 1°	< 1°	30	Pr. 2a	18		greenish
" "	381	1050	12°	12°		10	Snap.	small		
Indian Ocean	382	3500	< 1°	5°	< 1°	220	Kue	178	C 0—25	15—00
									B 140—178	15—88

ad column *position*: The exact position is to be found in a table given by van Riel in Vol. I, Chap. I.

ad column *depth*: The depth is the average of wire- and echo-depth, rounded off to 50 m except for the shallow soundings. For fuller data see Pinke in Vol. II, Part 2, Chap. I.

ad column *slope*: The slope was measured on the true-scale sections, drawn from the echo-soundings by the officers during the expedition. There are separate columns for the slope below the station, at the station and above the station. When the ship sailed up the slope to the station and then down again there are two figures for the slope below the station. In general the steepest slope measured is nearest the actual declivity of the bottom, the others lying more oblique to the direction of maximum slope.

ad column *distance to coast*: A few very small islands have not been taken into account.

ad column *sampler*: The following abreviations are used: Pr. = Ekman-Pratje sampler, inner diameter of glass tube 3 or 2 cm. In. = valve constructed at the Meteorological Institute at de Bilt. An „a" is added when the inner glass and copper tubes have been left out. Kue = the long sampler of 4 meters. Snap. = snapper. Sig. = Sigsbee-sounding tube.

ad column *amount: or length* The original length of the sample is given as measured before removal from the sampler.

ad column *part.*: The figures refer to the number of centimeters from the upper end of the deposit (original length).

ad column *colour*: The only adequate method of describing the colours of sediments is by comparison with a standard colour scale. On the suggestion of Dr. Pratje I used Ostwald's scale: „Die Farbtonleitern von W. Ostwald", 3 Auflage, Unesma, Leipzig. In the table the colours are either given in descriptive terms or according to Ostwald's scale, at the time the sample was taken. For those not possessing this scale for reference a few remarks may be made to give some impression of the colours, but this is a very unsatisfactory method.

type of sediment determined by G. A. Neeb.)

Moisture	$CaCO_3$	Organic Nitro	Organic Carbon	Type of Sediment	Remarks
2,4	4,4			Terrigenous Mud	
12,1	18,1			" "	Upper end lighter grey, gradual transition. Very firm.
				Coarse	Shells with coating of manganese.
6,3	89,6	0,05	0,71	Globigerina Ooze	
8,4	5,5	0,22	2,80	Terrigenous Mud	
12,2	1,8			" "	
16,2	14,7			" "	
	trace			Terrigenous + Volcanic Mud	
4,2	42,0	0,12	1,40	Globigerina Ooze	0—½ cm = brown. Inv. part: 0—30 cm.
9,9	14,7	0,09	1,18	Terrigenous Mud	0—3 cm = brown. Inv. part: 0—30 cm.
3,2	58,8	0,055	0,72	Globigerina Ooze	0—½ cm = brown. Inv. part: 0—30 cm.
				Coarse	Fragment of mica shist and coral.
9,7	18,5	0,11	1,18	Terrigenous + Volcanic Mud	0—2 cm = dark brown. Stratification: see description of sample. Inv. part: 0—6 cm.
4,6	38,3	0,06	0,75	Globigerina Ooze	Colour: gradual transition.
6,0	33,1			" "	
5,5	45,7			" "	
5,7	46,8			" "	
5,1	45,8			" "	
5,2	35,0			" "	
5,7	38,3			" "	
7,6	28,4			Terrigenous Mud	
6,7	10,0	0,10	1,30	" "	Inv. part: 0—35 cm.
5,1	7,8	0,085	1,13	" "	
7,5	11,3			" "	Inv. part: mixture of whole length. Distance to station 155 about 4 km.
				Terrigenous + Volcanic Mud	
				" + " "	
7,7	34,9			Globigerina Ooze	0—5 cm = brown. Several indistinct layers.
4,2	27,5			Terrigenous Mud	

The colours found were as follows:
6-00-04; **9**-04-08; **10**-00-04-08-88; **14**-00-04-08;
15-00-04-08-13-83-88-96; **19**-04-08; **20**-00-04-08-83;
21-00-04-92-96; **26**-00-04-08; **27**-00-04-08-13;
28-00-04-08-13-83-88-96.

The underlined colours are those occurring as brownish darker surface layer, generally from 1—2 cm thick, but sometimes thinner and occasionally thicker, up to 20 cm. The fat numbers denote groups forming a fairly complete and regular transition from the light and pale shades of **6** to the almost black shades of **28**. The group **19** might be placed between **10** and **14**. The groups can also be tabulated according to the intensity of the colour:

	less intensive			more intensive
light		6		
			9	
	10			
				19
		14		
	15			
		20		
	21			
			26	
	27			
dark	28			

← green ——→| yellow →|← reddish brown
–83–88–92–96–00–04–08–13

The colours with a greenish tinge are numbered -83-88-92-96, while -00 fits on and is also greenish towards yellow. From -00 to -13 is greenish-yellow, via yellow to more reddish-brown. The intensity of the colours is weak. Although the variation in colouring is wide, the range is seen to be restricted when compared with the whole scale (42 out of 672 shades).
Special remarks are given in the last column.

ad column *moisture*: Moisture is the amount given off at 105° C from the dryed sample.

ad column *remarks*: When the sample showed a darker, brownish surface layer this is stated in the last column.
Inv. part = Investigated part. Centimeters and colour are always given from the upper end downwards.
Where the reference „Inv. part" is absent, the whole length of the sample has been used for the investigation. For further details see introduction to this Part.

Station 33.

Sample stratified; 0—2 cm = 27-04, 2—6 cm = 15-00, 6-20 cm = 28-00, 20—25 cm = 28-00 with little mica, 25—27 cm = 28-00 with much mica, a few mm dark brown consisting of plant remains, 27—30 cm = 28-00, coarse grain. Plant remains appear to be frequent on the bottom in this region; see also station 39a and 41.

Station 39[1]

A small piece of wood was caught in the jaws of the sampler.

Station 41

A few small bits of wood were found in this sample. It was stratified: 0—2 cm = 20-04; then a stratum 2—3 cm with much mica = 21-92; fine-grained stratum 3—10 cm = 15-00; fine-grained stratum 10—11 cm = 21-00, with mica; 11—38 cm = 15-00.

Station 102.

This sample contains a large and irregularly distributed amount of angular rock fragments. To this must be attributed the exceptional divergence between the two determinations of $CaCO_3$.

Station 189.

Two soundings, the first was stratified, but the second not, although the distance between the two is probably only 2 km.

Station 278.

The smaller sampler brought up a stratified sample: 0—41 cm = 26-00; 41—45 cm = 21-00, sandy; 45—48 cm = 26-00; 48—51 cm = 21-00; 51—79 cm = 26-00.

The long sample was as follows: 0—29 cm = 26-00; 29—32 cm = 21-00, sandy; 32—35 cm = 21-00; 35—168 cm = alternating strata of 21-00, 26-00 and 27-02. Although the ship drifted only about 1 km the stratification is similar but not identical in the two samples of this station.

The distance between the soundings in the Kaoe bay is as follows:

First to second sounding of station 278: about 1 km; first sounding to station 279[1]: about 2 km; station 279[1] to 280: about 13 km; first to second sounding of station 280: about 0,5 km.

Station 279[1]

This long sample was stratified in greyish and greenish colours about 27-02. From 65—71 cm occurred a sandy stratum: 21-00.

Station 301

This sample shows a very delicate stratification:

0—1 cm = 27-04; 1—2 cm = 14-06; 2—5 cm = dark; 5—8 cm = light; 8—8½ cm = dark;

8½—20 cm = dark; 20—20½ cm = dark; 20½—26 cm = 14-02; 26—29 cm = dark; 29—32 cm = light; 32—36 cm = brown-grey; 36—39 cm = dark; 39—41 cm = light; 41—41½ cm = dark; 41½—46 cm = light; 46—46½ cm = dark; 46½—50½ cm = grey; 50½—53 cm = light; 53—54 cm = dark; 54—64 cm = grey; 64—65 cm = dark; 65—68 cm = light; 68—79 cm = 21-04.

Station 330

This long sample is delicately stratified, showing about 74 layers, varying in thickness between ½ and 4 cm, and differing slightly in colour without sharp margins.

Station 347

Thanks to the great weight of the sampler it carried right through some hard layers of coarse volcanic ash. A coarse stratum occurred at 47—54 cm and at 133—136 cm.

Station 358

This long sample contains a large number of layers due to volcanic eruptions, presumably of the Banda volcano. The colour of the normal Volcanic Mud shows a gradual transition from 15-04 to 21-00. Each of the layers of ash is darkest and coarsest at the lower end, colour 28-00, gradually growing finer and lighter upwards until it merges imperceptibly into the normal mud. The thickest layers are the most coarse and are spotted in colour. These strata are found about at 3—6 cm, 27—28 cm, 29—40 cm, 51—56 cm, 71—81 cm, 83—85 cm, 93—95 cm, 105—108 cm, 115—123 cm.

Station 373

This sample is stratified. 0—2 cm = dark brown; 2—9 cm = 15-00, especially in lower part Globigerina; 9—13 cm = 27-06; 13—21 cm = 27-04; 21—46 cm = about 5 indistinct strata 15-02; 46—64 cm = about 10 more distinct strata 15-02; 64—72 cm = 15-00.

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but not directly of the degree of admixture, as the lime content of the clay fractions must be subtracted in these fractions to ascertain the content of terrigenous components.

In Table 2 the data collected during the Snellius-expedition as to the sediments are brought together, while the sediment type is given.

1. VOLCANIC MUD AND THE VOLCANIC MATERIAL OF THE MIXED MUDS

Volcanic Muds are deposits in which recent volcanic material predominates, usually aeolian deposits of volcanic ash. There may also be material washed off from recent submarine volcanoes or volcanoes which rise up directly from the sea and on the coast. In the latter cases lava flows which extend into the sea may be eroded.

The distribution of Volcanic Mud, as will be seen on Map I, corresponds to the position of the recent volcanoes, principally in two areas of the eastern Netherlands Indian Archipelago, viz. in the region occupied by the series of volcanoes which runs from Java to Banda Api, and in the region which embraces great portions of the Celebes sea and the Molukken sea.

In the 75th Bulletin of the Netherlands Indies Volcanological Survey (1936) there are given „the volcanoes which since 1600 A.D. showed magmatic eruptions or periods of increased volcanic activity". These volcanoes are marked on the map by their numbers and a black star.

The two active volcanoes known on Mindanao are added to these, i.e. the Ragang and the Calayo (117, 118).

The eruption material from most of these volcanoes has been examined. But there is a difficulty in comparing the mineralogical composition of the volcanic ash of the deep-sea sediments with the composition of the eruption products as described, namely that the geologists, with the exception of Wichmann and Esenwein, have confined themselves to the examination of solid rocks and paid little or no attention to the volcanic ash of the various eruption periods, in spite of the composition of the ash being actually much more constant.

As far as possible the Volcanic Muds are classified below according to the volcanoes from which the material is derived.

a. *Volcanic Mud derived from Tambora ash*

Samples 167, 170, 173, 172, 183, 184 and 180 all have a similar mineralogical composition which is characterised by a very high content of volcanic glass, usually brown in colour, and by the presence of beautiful idiomorphic plagioclase, augite, olivine, magnetite and apatite, as well as biotite of a golden brown to dark brown or greenish brown or even orange yellow to red brown colour.

The volcanic glass is angular with a porous structure. The augite is green, sometimes yellowish or bluish green. The biotite occurs as fresh flakes which are usually present in the form of idiomorphic hexagons.

The mineralogical composition of these samples is given in table 3 and the mechanical composition is graphically represented in fig. 1.

The following notes apply to the mineralogical tables: No counts could be made of the fractions which compose a small percentage of the sample; the component parts in these cases are indicated only by a sign. The component parts of the remaining fractions are expressed in percentages of the fraction. To give an idea of the part each fraction makes up of the sample the percentages of the fractions are given after the composition.

The fractions are indicated as gr. (= gravel) for the particles larger than 2 mm and as fraction 1—6 for the particles 2—1 mm, 1—0,5 mm, 0,5—0,2 mm, 0,2—0,1 mm, 0,1—0,05 mm and 0,05—0,02 mm respectively. Counting the 6th fraction requires a great deal of time so that it was usually considered sufficient to give the percentages which the total mineral content, the total calcium carbonate content and the various siliceous organisms form of the fraction; only where there is an essential difference between fractions 5 and 6 an extra account is given. Siliceous organisms, calcareous sponges, discoasteridae, coccolithes and rhomboedra of calcite and dolomite, as well as pyrite are present principally in the finest sand fractions and are therefore determined separately in these.

As plagioclase I and II basic (anorthite, bytownite and labradorite) and acid plagioclase (andesine, oligoclase, albite) are indicated.

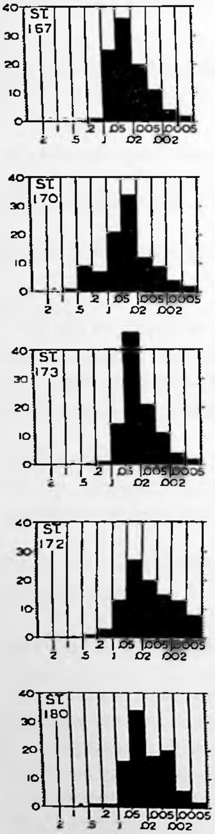


Fig. 1. Mechanical Analyses of Volcanic Mud, derived from Tambora-ash.

The mechanical analysis (fig. 1) of samples 167, 170 and 173 shows a distribution of the particles such as is frequent in aeolian volcanic ash. The small samples 183 and 184 consist principally of particles 10—100 μ in diameter, by far the greatest component being volcanic glass, while there are no clay particles at all, the mineral constituents consist therefore of pure volcanic ash. These five samples show a great resemblance to one another, both mechanically and mineralogically.

The mechanical analyses of sediments 172 and 180 indicate a similar composition, the chief grain diameter amounts also to 5—100 μ, but the clay content of the samples is higher than in the first. From table 3 it may be seen that in both these samples, besides the typical minerals of the volcanic ash mentioned above clay casts and secondarily formed pyrite occur as well as some hypersthene and hornblende.

The rock particles of all these samples are usually rich in glass and in the glass beautiful idiomorphic plagioclase, angite, olivine and apatite can be observed.

The mineralogical composition of the volcanic ash in these 7 samples, as well as their chief distribution in the Bali sea, the Flores sea and to the north of the Paternoster and Postilions islands, allow the conclusion to be drawn that they are derived from the Tambora.

Of the volcanoes surrounding the Bali and the Flores sea the Batoer (155) and the Agoeng (84) on Bali are composed of pyroxene andesite and basalt, which cannot contain biotite, but do contain augite, hypersthene, olivine, apatite and a little hornblende. Probable an admixture of Batoer ash accounts for the presence of hypersthene and hornblende in sample 172. Stehn (155) tells that occasionally K.P.M. steamers were troubled by ash north of Singaradja during the eruption of the Batoer in 1926.

The Rindjani on Lombok, according to A. Simon (150) is composed of augite-olivine-andesite and basalt, which may contain small quantities of bronzite, magnetite and hornblende.

The Sangean Api on the island of Sangean, according to Verbeek's research (168) which was directed to the rocks of the west coast, is composed of olivine-containing augite-andesite and basalt, which contain plagioclase, augite, olivine, magnetite and apatite. This corresponds to the mineralogical composition of sample 169 mentioned later.

The rocks of the active volcanoes on Flores according to Kemmerling (88) all belong to the basaltic andesites, none of the rocks described contain biotite.

Finally the Tambora, according to the research by J. J. Pannekoek van Rheden (129), who examined a great number of rocks, consists of leucite-basanite and leucite-tephrite; some of these rocks are rich in volcanic glass. The leucite occurs only in the ground mass. In the leucite-basanite are found plagioclase (labradorite), pale green augite and olivine as phenocrysts; in the leucite-tephrite these are plagioclase, augite, biotite and sometimes magnetite. The groundmass of the leucite-basanite may consist of little to much dark glass with plagioclase, augite, magnetite and leucite. The leucite in these rocks sometimes shows a weak birefringence. The groundmass of the leucite-tephrite varies in composition; it is usually rich in glass; plagioclase is of constant occurrence; augite, magnetite and isotropic globules of leucite are sometimes found and sometimes not.

The absence of leucite amongst the phenocrysts explains why leucite is not found among the minerals occurring in the Volcanic Muds shown in table 3. In the glass of these sediments the leucite occurs rarely.

The biotite of the leucite-tephrite is brown; often fresh, well formed, sharply defined six-angled flakes are described: this is in accordance with the habitus of the biotite of the samples in table 3.

In a sample of tuff from Tambora *), slightly affected by solfatara action, the same minerals were recorded as were found in samples 167 and 170, moreover apatite was found, not mentioned by Van Rheden.

The Tambora ash, therefore, is directly distinguishable by its composition from the ashes of the surrounding volcanoes, which are of andesitic or basaltic composition.

The wide distribution of a comparatively thick layer of ash which is observed here, moreover, is only possible as the consequence of a violent eruption, such as that of the Tambora in 1815.

Samples 167, 173, 172 and 180 are 29, 15, 22 and 42 cm thick respectively, while 170 is marked as „large". Roughly speaking it can be calculated from the mineralogical and the mechanical composition that samples 167, 170 and 173 consist for about 80% of volcanic ash and 20% of organisms and clay particles. The content of volcanic ash for samples 172 and 180 is about 60%.

On Map II these large samples which consist for 60—80% of Tambora ash are shown by shaded circles. The sediments which contain between 3 and 30% Tambora ash are indicated by circles as well as the small samples 183 and 184; the sediments marked by broken circles contain very small quantities of ash. From 3—30% Tambora ash occurs in the mixed deposits of Terrigenous and Volcanic Mud at stations 171, 166, 181, 175, 176, 179, 178, 31, 317a and 197 (cf. Table 3) in the Globigerina Ooze 174 (Table 25) and in the Coral Muds 165 and 182^{L} (Table 26). Very small amounts of Tambora ash could be traced in the Terrigenous Muds 28 and 30 and in the Globigerina Ooze 185 (Table 25).

The black line in Plate II shows the observed limit of the distribution of Tambora ash. The dotted line represents the distribution of Tambora ash as Zollinger (191) imagined it to be in connection with the prevailing east wind at the time of the catastrophic eruption of 1815 and with the observations concerning the rain of ash on the islands of the Indian Archipelago (see Table 4 and Plate II). The correspondence with the theoretic distribution in the area north of the Lesser Sunda Islands proves fairly good. In the western part of the Banda sea the deposits of Tambora ash may have been overlaid by the eruption products of the Batoe Tara. South of the Lesser Sunda Islands, however, no indications are found of the occurrence of Tambora ash, neither in the Sawoe sea nor in the Indian ocean. This circumstance cannot be due, except for a strip along the coast of Flores, to an overlaying by other volcanic ash, and the sampled thickness of the Terrigenous Muds is here deep enough to reveal the possible presence of Tambora ash. For the area south of the Lesser Sunda Islands, therefore, the theoretical ellipse of the distribution of the ash is not supported. The theoretical elliptic form of the distribution of the ash was based upon the assumption of strong trade winds, in this case the east wind. In actuality however, there was no question of a strongly prevailing wind. Van Everdingen (53) records observations, in the months of February and August at 2 km height at Koepang, of winds from all 8 directions. Not only the direction but the force of the wind varies. Consequently

*) This sample of tuff from the collection of Pannekoek van Rheden was kindly placed at my disposal by Dr. P. Kruizinga of the Mijnbouwkundig Instituut at Delft.

TABLE 3. Mineralogical Composition of Volcanic Mud, derived from Tambora-ash,

No.	Fr.	rock particles and pumice	plagioclase I	plagioclase II	quartz	volcanic glass	augite	hypersthene	olivine	green hornblende	red hornblende	actinolite	biotite	chlorite	apatite	epidote	zircon	magnetite and ilmenite
167	1	†																
	2	†																
	3	†				†												
	4	7	0,5			84	1		0,5				3					
	5	23	10			55	1		0,3				3		1			0,5
	6																	
170	1	†																
	2	4				37							4					
	3	6	5			46							5					1
	4	8	4			60	1						4					0,5
	5	13	7			67	2		0,2				2		0,5			0,5
	6	6	4			78	1						0,5		0,5			0,5
173	2																	
	3	2	1			36							11					
	4	14	8			67	1						4					0,5
	5	13	10			68	2		0,5	0,2	0,1		2		1			0,5
	6	13	6			77	1		tr.	tr.	tr.		1		0,2			0,2
172	2	30	tr.															
	3	9	16			28				2			0,5					
	4	14	8			37	2	1,2		0,7			4					
	5	28	6			55	1	0,5	tr.	0,2			0,2		0,2			1
	6	18	7			58	0,5	tr.	tr.	tr.			0,2		tr.			0,5
180	2																	
	3												0,5					
	4	6	1			10	1						1					
	5	25	11			31	14	tr.	tr.	0,5			1		0,5			5
	6	20	12			46	3			0,5			0,5		0,5			1
183	S		†			††	†						†					
184	S	†	†			††	†						†		†			
171	P	†	†			††	†						†					
166	2	†																
	3	2	2			2	tr.									tr.		
	4	3	1			2	0,5			tr.			tr.					tr.
	5	12	3			12	3	tr.		tr.			1					0,5
	6	3	3			17	2			tr.			0,5					0,5
181	1																	
	2	12																
	3	7	3	tr.		2												tr.
	4	16	6	tr.	tr.	2	0,5	0,5		0,3			0,3					0,3
	5	24	10	tr.		6	10	0,5		4	tr.		0,3		0,1			2
	6																	
175	1	†																
	2	4																
	3	1				tr.							tr.					
	4	8	1			1	1						0,5					
	5	36	13			6	9	1	tr.	1					tr.			2
	6	12	12			8	2	0,3		0,5								2
179	2	2											1					
	3	1				tr.	tr.											
	4	0,5	tr.			tr.	tr.											
	5	19	11			2	9	tr.		0,3					0,3			3
	6	12	8			6	4			tr.	tr.		1					2
178	2	2											tr.					
	3	0,5																
	4	0,5		tr.	tr.	0,5												
	5	13	3			4	4	0,3		0,5			0,3				tr.	2
	6	5	2	tr.		2	0,5			0,5	tr.		1,5					1,5
31	1																	
	2																	
	3												1					
	4		0,3	tr.		4							0,6					
	5	7	6	4	2	18	1,5	0,5		1		0,5	1,5	1	0,3	0,5	tr.	1
	6																	
317a	2	†											†					
	3	3	1			3	0,5			tr.			2					
	4	5	5			3	1	0,5	tr.	0,5			2					tr.
	5	28	16			10	4	2	tr.	1	0,5		2			0,1		2
	6	14	8			9	1	0,5		0,5	0,5		0,5					3
197	2	†											†					
	3	38	35			5	2	2	2,5	6	0,5		2					0,5
	4	29	44			3	3	4,5	1	7	1		0,5					1
	5	35	30			11	3	2	tr.	5	1,5		tr.		0,5			4
	6																	

and of Terrigenous + Volcanic Mud, containing Tambora-ash.

limonite	pyrite	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	shell fragments	Echinoderm fragments	calcareous Sponges	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
																	0,04
																	0,01
				†													0,01
			96	1						0,5	1,5	0,5	1		1,5	1	0,8
			94	2	0,5					2	4,5	1	0,5		1,5		25,3
			88	3	0,5					7	10,5	1	0,3	0,2	1,5		35,9
				†		†											0,1
			45	55							55						0,9
			63	33	1		0,3			0,7	35	0,5	1,5		2		9,0
			77,5	20							20	0,5	2		2,5		7,1
tr.			92,2	6	0,3					0,5	6,8	0,5	0,5		1		21,4
0,3			91	2,5						4	6,5	1	1	0,5	2,5		33,9
				†	†												0,03
			50	42	3		0,2			1,8	47	1	1,5		2,5	0,5	0,3
			94,5	3	0,5					0,5	4	0,5	1		1,5		1,5
			97,3	2	0,1					0,3	2,4	0,1	0,1	0,1	0,3		14,0
			98,5	1							1	0,2	0,1	0,2	0,5		45,7
		tr.	30	69	1						70						0,3
		13	68,5	29	2		0,5				31,5						0,6
		12	79	17	1	tr.	tr.				18		3		3		3,2
	tr.	2	94,1	—5,5—							5,5	0,2	0,2		0,4		12,8
	tr.	4	88,5	—5,5—						3	8,5	1	1	1	3		26,8
		100	100														0,3
		94	94,5	0,5							0,5	1	4		5		0,9
		59	78	—10—		1					11	1	10		11		1,5
	tr.	1	89	—4—				0,5		4	8,5	1,5	1		2,5		16,3
	0,1	3	86,6	—3,5—				0,5		4	8	3	1,4	1	5,4		34,3
				†			†					†	†	†			
				†			†	†				†	†				
	1	10	66	8	8	4				14	34						
		†		†									†				0,04
		29	35	60							60	1	4		5		5,9
		28	34,5	60	0,5	tr.	tr.				60,5	1	4		5		12,6
		5	36,5	45	2		tr.	0,5	2	8	57,5	4	2		6		13,2
	0,5	2	28,5	—28—				3	5	15	51	16	3	1	20	0,5	13,8
		†			†												0,06
		2	14	83	3						86						0,5
		3	15	82	3				tr.		85						1,4
		13	39	54	2			tr.		3	59	tr.	2		2		3,7
	0,1	4	61	—32—						5	37	1	1		2		10,7
	2	4	34	—41—				1	tr.	10	52	8	5	0,5	13,5	0,5	13,4
																†	0,1
		15	19	80		1					81						0,3
tr.		48	49	50			tr.				50		1		1		0,3
		40	51,5	—44—			tr.				44	1	3,5		4,5		1,4
	tr.	4	72	—24—			tr.			2	26	1	1		2		4,0
tr.	2	4	43	—30—				1		14	45	7,5	2	2	11,5	0,5	14,0
		56	59	41							41						0,2
		68	69	30			tr.				30	tr.	1		1		3,4
		71	71,5	22	1						23	0,5	5		5,5		2,3
		28	72,6	23	1		tr.				24	3	0,4		3,4		4,4
	7	10	50	—8,5—						10	18,5	23	7	1	31	0,5	10,2
		5	7	93	tr.						93						0,3
		20	20,5	79	0,5						79,5						0,8
		36	37	56	1						57	1	5		6		2,8
	1	7	35,1	54	2			0,3		3	59,3	4	1		5	0,6	4,8
	4	8	25	40	2					9	51	19	4	1	24	tr.	10,2
		†															0,02
		98	98	2	tr.						2						0,8
		92	93	—6—		1					7						2,6
		86	91	—9—		tr.					9	tr.	tr.		tr.		4,0
	0,5	37	82,3	—15,5—		0,2					15,7	2			2		6,1
	2	17	77					tr.			16	6	0,5		6,5	0,5	12,9
		†		†													0,2
		16	25,5	68	1						69	3	2,5		5,5		1,0
		18	37	44	1						45	3	15		18		2,5
		3	68,6	—26—						1	27	3	1		4	0,4	9,4
		2	39	—28—						13	41	13	6	1	20	tr.	13,3
																	0,2
		4	95,5	1,5						2	3,5						2,1
		1	95	1						3	4	0,5	0,5		1		2.2
		1	93	2						3	5	1	1		2		9,7
	0,5	1	89								5	4	1	0,5	5,5	0,5	21,4

it may be assumed that the discrepancy between the theoretical and the observed distribution of the Tambora ash should be attributed to the deviations of the trade winds during the eruption.

Before 1815 the Tambora had shown no activity within the memory of man and the eruption in 1815 was a terrible catastrophe. Zollinger says of the eruption:

„Der Ausbruch der Gunung Tambora erschütterte jene Gegenden der Erde so gewaltig, dass die Wirkung davon im ganzen Umkreise der Molukken, sowohl als in dem nähen Java, den Inseln Celebes, Borneo und Sumatra, folglich in einem Umkreise von mehr als tausend geographischen Meilen gefühlt wurde. Auf allen diesen Inseln spürte man die Explosion durch eine wiederholte zitternde Bewegung des Bodens sowohl, als durch den entsetzlichen Wiederhall des unterirdischen Krachen und Donnerns".

From April 5th ash was thrown out; the principal eruption and great explosions seem to have taken place on April 10th and 11th, in which the top of the mountain collapsed, after which the activity subsided. Corresponding to this, three strata were found at Sanggar, the deepest consisting of fine ash, the following of lapilli in which the deeper lapilli were the largest, and the upper layer consisted of coarse sand. Between April 14th and July 15th very fine and light ash rose from the volcano, which was dispersed by the wind.

Table 4 shows what an enormous amount of ash was thrown out during this eruption.

TABLE 4. Thickness of Tambora-ash layer after the eruption of 1815, according to Zollinger

East			West		
Position	Ash-layer in cm	Distance to Tambora	Position	Ash-layer in cm	Distance to Tambora
Sanggar (1)	90	± 20 km	Soembawa (3)	60	70 km
Bima (2)	45	90 km	W. Lombok (4)	45	220 km
			Bali (5)	30	300 km
			Banjoewangi (6)	22	400 km

At stations 167, 173, 172 and 180 of the Snellius-expedition also thick layers of Tambora ash have been deposited. These samples are 29, 15, 22 and 42 cm thick respectively; the two first mentioned consist for 80% of ash and the two last mentioned for 60%. If the difference in specific gravity of the volcanic ash, the clay and the organisms is disregarded, the thickness of the layer of ash at the place of samples 167, 173, 172 and 180 may be calculated at about 23, 12 13 and 25 cm respectively. It is not impossible that the ash-layer at stations 167, 173 and 172 is even thicker, but sample 180 is bounded below by a layer of coarse ash and sample 167 by a layer of clay, so that at both these stations the entire layer of ash has been sampled.

The thickness of the layer of ash can be calculated in deposits mixed with other sedimentations from the mechanical composition of the sediment combined with the results of the mineralogical research of the sand fractions. In this calculation use is made of the observation that the particles of ash are not smaller than 5 μ; that the Tambora ash displays the habitus of freshly fallen ash, although it has been in contact with the sea water for 115 years and that the röntgenographic examination of the clay fractions carried out by Dr. Favejee, showed that they contain practically no weathering products derived from the ash, but correspond in composition to that of the Terrigenous Muds and Globigerina Oozes of the same region. The mechanical analysis must be imagined as composed of two curves, that of the Tambora ash with a peak in the fraction 50—20 μ and that of the terrigenous clay particles with the peak in the fractions 5—2 μ. The content of ash is obtained by subtracting from the part with a peak in the fraction 50—20 μ the content of foreign components such as calcareous and siliceous organisms, known from the sand research. In a similar way the content of terrigenous components may be calculated.

The only samples of mixed terrigenous and volcanic material that proved to be intact were 175 and 179. In the 25 cm long sample 175 the ash was mixed with clay in the whole sample, in which there was a lower ash content above than below. In sample 179, however, the Tambora ash proved to be principally in the upper 10 cm. The ash content of the two samples represents a layer of about

3 cm. It has only been proved for 179 that this layer represents all the material deposited since the eruption of 1815.

In the 30 cm long sample of Globigerina Ooze 174 it was seen that here a layer of 3 cm ash was deposited upon the Globigerina Ooze, while above this a layer hardly 1 mm thick of Globigerina Ooze had formed.

The thickness of the ash layer on land declines, according to Zollinger, more slowly in a westerly direction with the distance from the Tambora than in the easterly direction (see Table 4). This must also be the case, of course, with the aeolian distribution of the ash above the sea. There is an almost linear connection between the thickness of the ash-layer and the distance from the volcano in a particular direction.

The sediments 167, 179 and 180 which lie respectively 120, 250 and 250 km to the east of Tambora contain ash layers calculated at 23, 3, and 25 cm thickness. The ash layers of samples 167 and 179 by a linear connection may be brought more or less into correspondence with observations at Sanggar and Bima (Table 4), while on the other hand an ash layer of 25 cm thickness for sample 180, considering the contrast with sample 179, is remarkably high.

Sediments 174, 173 and 172 which lie 80, 200 and 330 km west of Tambora, contain ash layers of 3, 12 and 13 cm thickness; the ash layers are therefore thinner than the observation on land would lead us to expect.

We see, therefore, that on the one hand there is a contrast between the content of the samples taken to the east and to the west of the Tambora and on the other hand the ash layer at St. 180 in the deepest part of the Flores sea is much thicker than in the neighbouring sediments in the shallower parts of the Flores sea. These differences cannot be caused by the effect of the wind upon the distribution of the ash. It must be assumed that it is due to ocean currents which have carried the ash, while settling, in the direction indicated by samples 173, 174, 167 and 180 from west to east. The presence of currents in the direction of the west-east axis of the Bali and Flores seas is demonstrated also by the fact that the amount of clay deposited at stations 173, 174 and 167 since the eruption of 1815 is less than the amount of clay deposited at stations 172, 175 and 179 during the same period.

In sediment 167 the sampling has gone deeper than the ash layer, so that at this spot the amount of clay deposited since 1815 is probably less than the layer of clay of 4 cm which represents the total clay content of the sample.

In sediment 173, 2 cm clay has been deposited with the ash, in any case, therefore, a small amount even if it is taken into consideration that the lower limit of the ash is not clearly marked.

In sediment 174 the volcanic ash lies upon the Globigerina Ooze, while above it only about 1 mm of Globigerina Ooze has formed.

In sediment 175 Tambora ash was found in the entire sampled layer of 25 cm., the ash content declining towards the top. The terrigenous components of the sample, which compose about 60% of it, here represent, thus a layer of at least 15 cm, as it is not certain that the lower limit of the ash deposit had been reached.

In sediment 179 Tambora ash occurs in the upper 10 cm. The ash layer has already been calculated at about 3 cm for this sample. The Terrigenous Mud deposited at the same time at this station represents a layer of about 6 cm thickness.

In sediment 172 at least 7 cm of clay has been deposited with the ash; for in this case also the lower limit of the ash is not clearly marked.

Finally at St. 180 in the deepest and broadest part of the Flores sea much clay has also been deposited since 1815. The sample consists of about 60% of volcanic ash, 5,2% carbonate of lime and about 5% of siliceous organisms. The clay content, in this case the only terrigenous component, amounts to 25 to 30%. The Terrigenous Mud thus, represents a layer of about 11 cm.

The same sediment, 180, shows a stratification in microscopic examination. At 38—42 cm depth in this sediment coarse ash of about 50—200 μ diameter is deposited, this is followed upwards by a layer of about 10 cm depth which consists of finer ash of about 20—80 μ mixed with a little clay; all this, therefore must have settled fairly rapidly as it must be assumed that the rate of sedimentation of the clay is fairly constant. Further upward the ash content declines while the clay content increases. In the upper 25 cm the ash is very fine, always less than 30 μ diameter and the content of volcanic glass increases relatively, that is to say the specific gravity of the settling particles decreases

regularly. Here, therefore, the remarkable fact is revealed that at station 180 the finest particles of Tambora ash are still found settling 115 years after the eruption of the volcano had taken place. It cannot be supposed that this material was washed down the slopes of the Tambora into the sea by rivers, as then the sediment would not have a constantly declining grain diameter in the volcanic ash, nor an increasing content of volcanic glass. It may be remarked in this connection that in sediment 171, taken only 20 km from the coast of east Java north of the Sampean delta, Tambora ash could be detected, but no Raoen ash in spite of the fact that the Sampean river carries off Raoen ash. It seems that here the river deposits its coarser material nearer to the coast, in which the selection of the material by the breakers plays a part, as the present writer perceived from the composition of the coast sands of north Java. It is thus certainly the aeolianally dispersed Tambora ash which settles after 115 years at St. 180. This does not exclude the possibility of there being some ash from the Sangean Api included in the material collected at St. 180; some of the augite in 180 namely, is of a darker green than in the other samples.

An idea of the retarding effect on the settling of ash particles by currents in the Flores sea may be gained by comparing the rate of settling at St. 180 with the rate of settling in still water. If the rate of settling valid for mechanical analyses in the tropics, at a specific gravity of about 2,7 and a temperature of about 27° C, is applied to the rate of settling of particles in sea water, while neglecting the higher specific gravity and the higher upward pressure of sea water, i.e. the lower rate of settling in it, as well as the lower temperature in deeper layers we get the following values:

100 μ	diameter,	rate	of	settling	in	water	20 m	per	hour
30 μ	„	„	„	„	„	„	1,8 m	„	„
5 μ	„	„	„	„	„	„	5 cm	„	„
1 μ	„	„	„	„	„	„	0,2 cm	„	„

Sediment 180 lies 5100 m deep. In fresh water without currents and at even temperature the particles of 100, 30, 5 and 1 μ would take 11 days, 4 months, 12 years and 300 years respectively to reach the bottom at this spot. The delay in settling for the 30-5 μ particles is thus considerable. It must, however, not be forgotten that the specific gravity of the later settled ash is lower than 2,7 because it consists chiefly of volcanic glass. According to George (58) the specific gravity of powdered volcanic glass varies between 2,1 and 3,0, while with the decline of the SiO_2 content the specific gravity increases. The s.g. of the powdered volcanic glass will therefore not deviate much from 2,7. But considering the air or gas content of the volcanic glass, determinations of the s.g. of fine Tambora ash were performed. The s.g. of the volcanic glass varied from 2,5 tot 2,27. The ultimate rate of settling of volcanic glass of this kind is lower, as according to Wadell's formula (171) it is $v_p = 1gr_p^2\,(d_1 - d_2)/7\,\eta$, where

g = acceleration due to gravity (980 cm $sec.^{-2}$)
r_p = practical sedimentation radius in cm.
d_1 = density of the settling material
d_2 = density of the fluid
η = viscosity of the fluid

The ultimate rate of settling is thus proportional to the difference of density of the settling particles and of the medium. This difference is for clay and andesite particles about 1,7, for volcanic glass containing much air or gas the difference may be as little as 2,27 — 1,0 = 1,17. Hereby the rate of settling decreases ± 30%. The higher upward pressure and the increase of density of sea water with depth have little influence on settling velocities, 3% at most. Moreover the influence of temperature on settling velocities should be taken into consideration. The viscosity of the water varies rather considerably in small ranges of temperature. The curve of viscosity of water (see lit. 96) shows that the value drops about 50% from 0° C tot 30° C. The rate of settling at St. 180 near the bottom, therefore, is about half of that in the surface water. The settling time in the present case for the volcanic glass of 30-5 μ becomes from about 8 months to 24 years. These rates of settling, which apply to still water, lie also below the observed rates of settling at St. 180. All this proves that the dispersion of the Tambora ash and the manner and time of settling have been affected by currents.

Observations on marine currents are in general sparse. The Snellius-expedition carried out current observations at 8 stations, which have been worked out by Lek (100).

Amongst other things he calculated the resultant displacement („Restströme") of the water

at various depths. The currents were found to vary greatly both in strength and direction at different depths. One of these stations 317a lies in the eastern part of the Flores sea and forms part of the deep between Angelika-droogte and Soekoen, which is a sill between the Flores basin and the Southern Banda basin. Lek calculated the following resultant displacements:

TABLE 5. Resultant currents at station 317a according to Lek

Depth in m	Resultant Direction	Velocity in cm/sec
0	N. 22,5 E.	15,0
25	N. 22,0 E.	17,0
75	N. 39,0 E.	27,5
125	N. 84,5 E.	42,0
175	E.	43,0
300	N. 89,5 E.	28,8
600	S. 39,5 E.	11,2
1000	N. 85,0 W.	2,0
1500	S. 84,0 E.	5,0
2000	S. 26,5 W.	3,0

Between 125 and 300 m depth, thus, there is a displacement of water in an easterly direction, while on the other hand in deeper layers only slight displacements take place in a westerly direction. At St. 317a easterly currents, therefore, predominate. The fact that the sediment at St. 317a consists chiefly of clay proves that these are not bottom currents crossing a sill. The clay particles could not be deposited if at this station there were strong bottom currents. It may be assumed that in the Flores sea this displacement of water in an easterly direction also takes place and that resultant currents from the Bali sea to the Flores sea and the Banda sea are the cause of a diminished deposition of Tambora ash in the Bali sea and an increased deposition of this ash in the eastern Flores sea. But this does not explain why at St. 180 so much material was deposited, nor is the great difference in the thickness of the ash layer at stations 179 and 181, lying north and south of it elucidated.

For particles with a diameter of 100 μ, 30 μ, 5 μ and 1 μ the rate of settling in quiet fresh water at 27° C amounts to 20 m, 1,8 m, 5 cm and 0,2 cm per hour. For a current with a velocity of only 1 cm/sec the displacement of particles per column of water of 1000 m approximates:

100 μ	diameter:	1,8 km.
30 μ	„	20 „
5 μ	„	720 „
1 μ	„	18000 „

showing that the particles of Tambora ash of 30-5 μ may be displaced for considerable distances by currents of comparatively small velocity. Moreover it appears that clay particles (< 5 μ) may be transported over practically unlimited distances before reaching the bottom and from this it may be understood that the Terrigenous + Volcanic Muds may contain clay fractions which are in no way whatever connected with the mineral particles of the sand and silt fractions.

Knowing that the Tambora ash eruption took place 115 years before the samples were raised by the Snellius-expedition the rate of settling of Tambora ash can now be calculated. The ash layers deposited at stations 172, 173, 174, 167, 179 and 180 amount to 13, 12, 3, 23, 3 and 25 cm. The rate of settling of the Tambora ash at these stations varies, therefore, from 3 to 25 cm per 115 years. These are very high settling rates. But we must not forget that we are not dealing with constant rates of settling over a longer period of time here, as is the case with Terrigenous Muds, Globigerina Oozes and Red Clays, but that there may be long periods during which no ash whatever is deposited, when there is only slight volcanic activity or none at all.

The rate of settling of the terrigenous material in the sediments mentioned here will be dealt with in Chap. V.

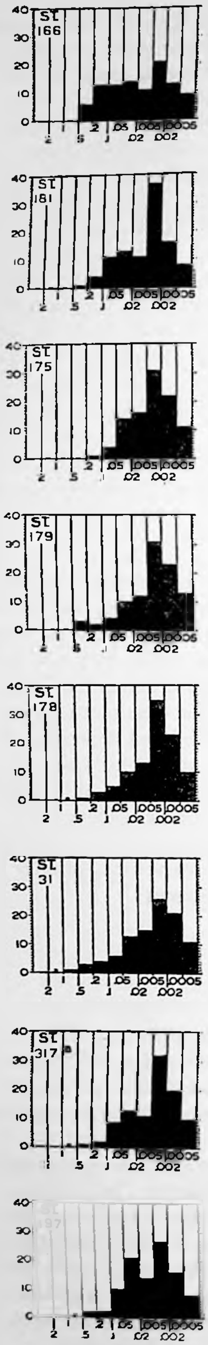


Fig. 2. Mechanical Analyses of Terrigenous + Volcanic Mud, containing Tambora-ash.

a[1]. *Terrigenous + Volcanic Mud, containing Tambora ash*

The area of mixed Terrigenous and Volcanic Muds surrounds that of the Volcanic Muds, according to definition. The boundary between the two kinds of sediment is fixed at an ash-content of approximately 50%. In the Terrigenous + Volcanic Mud examined the content of recent volcanic material varied between 3% and 30%. Smaller amounts of volcanic ash in the sediments is indicated by a pink line on map I.

In Table 3 the mixed deposits containing Tambora ash are included under the mineralogical composition of the Volcanic Muds. Fig. 2 gives the mechanical analyses belonging to them, all of which show a predominence of clay particles in the samples, indicating an important content of terrigenous material. Table 3 shows very clearly the presence of Tambora ash in the mixed muds, while the minerals found have the same habitus. The presence of terrigenous products, which form the chief components of these samples, is indicated in the mineralogical examination of the sand fractions only by the appearance of small quantities of quartz, actinolite, chlorite, epidote or zircon; in samples 175, 179 and 197 the only minerals found are of volcanic origin.

The minerals in sediments 197, 317a and 181 are distinguished from the pure Tambora ash by the presence of hypersthene and hornblende showing marked pleochroism. The hornblende is often present in long prisms, it also occurs idiomorphically in volcanic glass and is pleochroitic from yellowish green to green or greenish brown. Red hornblende is also found. The content of these minerals is highest in sediment 197, taken about 30 km north of the island of Paloeweh.

The *Rokatinda of Paloeweh* was in eruption in 1928 after a non-active period of 200—300 years. The eruption has been described by Neumann van Padang (122). The ash was dispersed by the prevailing east winds as far as from Paloeweh to Djember.

Esenwein (52) has described the lava, ash and pumice from this eruption as well as the recent Paloeweh rocks. They were all dacito-andesite-vitrophyres, characterised by the combination of plagioclase ($n => 1.55$) + hornblende + hypersthene. The estimated ratios were for rocks derived from the top of the Ili (1) and the north west side of the Ili (2), as follows:

	1	2
plagioclase	30%	25%
hornblende	10%	15%
hypersthene	5%	2%
augite	1%	
glass	50%	55%
magnetite	4%	3%

The hornblende is idiomorphic, pleochroïsm : α = bright yellowish brown, β = dark greenish brown and γ = grass green. $c/n_{\gamma} = 18°$. The habitus of both the hornblende and the hypersthene corresponds to that of samples 197, 317a and 181. Augite, according to Esenwein, was entirely absent from some of the rocks; the augite content of the remaining rocks is always small.

The ratio between hornblende and hypersthene varies a good deal. Volcanic ashes, in the present authors experience, yield in general more constant ratios.

The distribution of the Rokatinda material is comparatively limited. At St. 197 the ash content derived from this volcano may be taken at about 12%, calculated from the hypersthene + hornblende content, the mineral

ratios found by Esenwein and the course of the ash curve (fig. 2). The ash layer per 20 cm sampled layer would thus be approximately 2.5 cm thick.

In sample 317a the hypersthene content is higher than the hornblende. This sample lies in the region where not only Tambora ash and Paloeweh products are distributed but very probably there are ashes from the East Flores volcanoes Lobetobi Laki Laki and Lobetobi Perampoean as well.

The minerals of the sand fractions from St. 181 show a great resemblance to those of St. 180, although the content of Sangean Api material is relatively higher and the Tambora ash lower than in 180 (181: coarser rock particles, lower glass, lower biotite, relatively higher augite) and the admixture of Paloeweh material is more evident (higher hornblende and hypersthene).

In sample 179, 178 and 166 Rokatinda ash is sporadically demonstrable.

Close to Paloeweh, at a depth of 500 m and 1150 m samples 195 and 195^L were raised, which Kuenen describes as „one piece of lava'' and „lapilli and shells'' respectively. There is no doubt that Paloeweh products are present here, the coarse nature of which points to fairly strong currents at these stations. At St. 196 nothing was brought up, so that it seems as if sliding of settling material has taken place, as the incline at this station is as much as 17°.

At St. 31 the hornblende and hypersthene are of a different habitus, the hypersthene is only faintly pleochroitic and has sometimes ragged ends, the hornblende is fibrous or affected. Further, besides fresh, sometimes sexangular biotite (from Tambora) partly decomposed yellow and green biotite is present. The last belongs to the terrigenous part of the samples, with the hypersthene and hornblende. Minerals of the same kind occur in the Terrigenous Muds of Makassar Strait, which will be discussed later on.

At St. 176, as Kuenen says, a „trace of sand and clay'' was raised; this sample is therefore included in the Terrigenous + Volcanic Mud.

A preparation of the sand fractions at St. 171 proved to consist of 55% Tambora ash (rock particles, much porous brown glass, plagioclase, augite and biotite), a trace of green hornblende, 1% pyrite, 10% clay casts and 34% carbonate of lime. It is remarkable that there is no trace of Raoen ash here, while in the Sampean delta south of St. 171 it is largely existent, to my certain knowledge. Therefore the strip of Volcanic Mud along the north coast of East Java, marked on map I, should only be regarded as diagramatic; the strip has been kept narrow, possibly the effect of the volcanoes of Java is even more limited. Sample 171 in correspondence to sample S. 10, which according to Böggild (8) is a compact clay containing volcanic ash, is classified as Terrigenous + Volcanic Mud.

b. Volcanic Mud derived from Sangean Api material

St. 169 lies at only 2 km distance from the island of Sangean and at about 10 km distance from the volcano Sangean Api.

The mechanical composition of sediment 169 in Fig. 3 shows principally an aeolian volcanic ash with a peak in the fraction 100-50 μ. The smaller distance from the volcano explains why the ash is of coarser grain than in the Volcanic Muds containing Tambora ash. The gravel-content of sample 169, particles of basalt up to 1 cm, indicates that some washed off material from the Sangean Api contributes to the sediment.

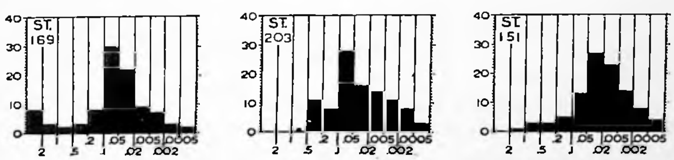


Fig. 3. Mechanical Analyses of Volcanic Muds, derived respectively from Sangean-Api-ash, Batoe Tara-ash, and ash of a Flores-Volcano.

The mineralogical composition, in table 6, is that of a basalt with a high augite and a low olivine content. The augite consists partly of ordinary green augite and partly of pleochroitic from light yellowish green to light grey blue mineral. The olivine is colourless, pale yellow or light green.

As has been said under *a*, Verbeek (168) in his Molukken report has described detached rocks from the west coast of Sangean, which contained plagioclase, augite, olivine, magnetite and apatite, while only a little volcanic glass and no hypersthene were found. The composition of the volcanic ash from Sangean Api is not known.

Ehrat (50) examined the products of the lava flow which came from the eruption of 1911; they

TABLE 6. Mineralogical Composition of Volcanic Mud, derived from Sangean-Api and Batoe Tara

No.	Fr.	rock particles and pumice	plagioclase I	leucite	volcanic glass with small leucites	volcanic glass	augite	hypersthene	olivine	green hornblende	red hornblende	biotite	chlorite	apatite	magnetite and ilmenite	pyrite	glauconite	zeolites	limonitic casts
169	gr.	99																	
	1	67					12		3						3				
	2	45	3				25		3						3				
	3	47	10			5	11		3	2		0,5			2				
	4	59	17			3	13		1	1		0,2			2			0,5	
	5	42	24			5	14		1	1	0,1	0,5		1	3			1	
	6																		
203	2	55																	
	3	74	5	3		8	5		1										
	4	63	5	6	1	8	11		2										
	5	43	16	10	2	12	9		1			tr.			1				
	6																		
204	S	†	†	†	†	†	†		†			†			†				
194B	1																		
	2	2																	
	3	2	tr.			1	tr.					0,5							
	4	5	0,5	tr.	1	0,5	0,3			tr.		0,5							
	5	30	7	2	5	3	7		tr.	tr.		2		tr.	tr.				
	6	15	7	2	1	4	3					1			1				
194A	1	†																	††
	2	2																	97
	3	3										1							93
	4	5,5				1	0,5					1							85
	5	13	3	2	2	1	2			tr.		0,2							72
	6	2,5	1	0,5	0,5		1					tr.							92
202	2																		
	3	1																	
	4	1	1			1,5	0,5												
	5	28	11	5	0,5	7	6	0,5	0,5	tr.		1			0,5				tr.
	6																		
205	1	†																	
	2	5	3									3					2		
	3	3	1			3		0,2							0,3		3		
	4	0,5	0,3			1	0,2					1					1		
	5	15	13		0,5	14	5	0,3	tr.	0,5	tr.	1	0,2	0,5	0,5		0,5		
	6															tr.			

had the same basaltic composition; he found it to contain dioritic inclusions, consisting of plagioclase, augite, biotite, hornblende and iron ore.

The mineral composition of 169 corresponds to the rocks described by Verbeek and Ehrat. This material is distinguished from Tambora ash by its high content of augite and low content of volcanic glass.

The distribution of the Sangean Api ash is probably limited, Rutten (142) (p. 655) classifies the Sangean Api as a volcano of minor activity. From the samples of the Snellius-expedition no more than indications of the presence of its ash in samples 169, 180 and 181 are obtained. The accretion of Sangean Api products in sediments 180 and 181 is probably due to marine currents.

In map I the Volcanic Mud around Sangean Api is diagramatically marked by a circle, in the same way as other volcanoes, where there is little evidence of the distribution of their ash.

c. Volcanic Mud derived from Batoe Tara material

The most peculiar mineralogical composition of Volcanic Mud comes to light in samples 203 and 204, situated near the volcano Batoe Tara, raised at approximately 30 km and 10 km from the volcanic island.

The mineralogical composition is found in Table 6. The samples are remarkable for their leucite content, the refractive index of which is between 1.500 and 1.505; in a few cases it is a little higher. The leucite of fractions 500-100 μ is seldom isotropic, often displaying twinning lamellae, contains many pits and hollows and is sometimes contained in volcanic glass. Fraction 100-20 μ presents an

and of Terrigenous + Volcanic Mud, containing Batoe Tara-ash

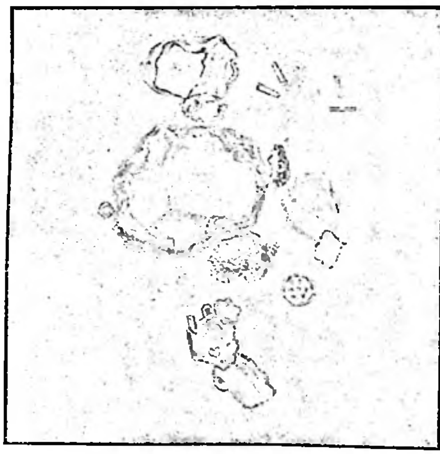
clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	shell fragments	Echinoderm fragments	Alcyonarian spicules	Bryozoa	Coral debri	calcareous Sponges	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
	99							1				1						7,0
	85	1	10	3			1					15						3,3
	79	6	7	1			1	3			2	20	1			1		2,3
	80,5	11	2		0,1			2		0,5	1,4	17	2	0,5		2,5		2,6
	96,7	2	0,3			tr.				0,1	0,2	2,6	0,5	0,2		0,7		8,7
	92,6	2	0,3							2	2	6,3	1	tr.		1		31,2
	92,5								0,1			5,2	2	tr.		2	0,3	23,0
	55	44	1									45						0,3
	96	2										2		2		2		10,9
	96	2										2		2		2		8,5
	94	2,5										2,5	2	1,5		3,5		28,1
	93,4											2	2	2	0,3	4,3	0,3	16,4
												†						
††																		0,1
96	98	2										2						3,2
74	77,5	20										20	1	1,5		2,5		5,2
70	78	14										14	tr.	8		8		3,0
24	80	17	0,5									17,5	2	0,5		2,5	tr.	8,2
28	62	12	0,5								5	17,5	11	8	1	20	0,5	19,6
																		0,04
	99	1										1						1,1
	97	1										1		2		2		7,0
tr.	93	1										1		6		6		4,5
	95	1										1	2	2		4		9,9
tr.	97,5	tr.										tr.	1	1	0,5	2,5		15,9
97	97	2,8			0,2							3						0,4
84	85	4										4	3	8		11		2,2
58	62	10										10	1	27		28		2,2
18	78	14	tr.								2	16	3	3		6		10,1
12	64											20	6	9	1	16		17,3
†		†																0,1
1	14	82	4									86						0,3
9	19,5	76	4		0,3							80,3	0,2			0,2		0,5
29	33	52	3									55	tr.	12		12		2,4
8	59	32	3								2	37	1	3		4		7,5
5	51											36	4	8	0,5	12,5	0,5	14,2

unusual appearance from the numerous small ikositetrahedrons of leucite in the brown volcanic glass. It is certainly a remarkable circumstance and confirms the idea that sea water has little decomposing effect upon the minerals, that the shape of the ikositetrahedrons is so well preserved. In fig. 4 a collection of leucite crystals of this kind in volcanic glass is drawn magnified 500 times. The drawing was made by Miss M. J. C. Schokker of Wageningen.

In the grit of these samples augite, plagioclase and apatite may be found contained in volcanic glass as well as leucite.

The augite is usually pale green, some of it is pleochroitic from yellowish green to grey blue. The biotite is pleochroitic from yellow to orange or golden brown, or from yellowish brown to dark brown. The olivine is colourless or yellow. All the minerals are idiomorphic.

The mechanical composition of 203 (fig. 3) is expressed principally by an aeolian ash curve. The small



St. 202 Fr. 5. 500 ×. *Drawing M. J. C. Schokker*

Fig. 4.

sample 204 is of somewhat coarser grain than 203 and contains practically no clay.

Hartmann (69) has examined the island of Batoe Tara (= sharp stone) or Komba and its rocks. The island proved not to be circular, on the east and west side especially, the coast curves inwards. The island volcano rises directly from the sea at an angle of 30—45°. There is no water and no bay of any size with a good shore, so that it is uninhabitable.

The volcano has built itself up from a depth of 2000 m; the highest point rises 747 m above the sea. The island is characterised by numerous flows of lava, many of which run into the sea. As he found a great number of bombs, the size of a man, Hartmann assumes that the magma must have been fairly tough and full of gas. (Stromboli type). The small thickness of the ash layers on the slopes of the volcano and in the sections of the volcanic mantle may be accounted for by the limited size of the island and the extreme steepness of the mountains. Most of the ash fell into the sea at the eruptions. The ashes from the flanks, mixed with other loose products reached the sea for the most part in the form of avalanches.

From the state of the vegetation at the time of his visit in 1931—1932 Hartmann concludes that the volcano has been at the solfatara stage for the last 40 or 50 years.

The eastern wall of the large crater displays a breach. From various reports from passing ships it is evident that the Batoe Tara was in a lively state of eruption during the years 1847—1852, which reached a climax in the destruction of the eastern part of the crater. A report by Wichmann seems to indicate that in the years 1852 to 1888 the volcano was still in a state of activity. According to the account of the coastal inhabitants of Lomblèn and Pantar, during the years 1888—1932 it only occasionally showed an increased activity.

It is therefore evident that the Volcanic Muds 203 and 204 must have been exposed to the action of sea water for at least 50 to 80 years.

The rocks which Hartmann examined he had collected on the southern slope of the volcano, from the top to 10 m above sea level. He found one leucite basanite in which augite, olivine, hornblende and plagioclase appeared as phenocrysts, while leucite, plagioclase, augite and olivine formed the groundmass. The other samples proved to be leucite basalt, in which there was no hornblende and in which leucite also occurred as phenocryst; part of the rock formed a transition between leucite basalt and leucitite. One of the samples contained, moreover, large biotite crystals. In two of the samples dark blue titan-augite was found.

Brouwer (26), who paid a two days visit to the Batoe Tara in 1937, collected rocks on the south coast of the island. While Hartmann found a lot of olivine in a sample which he marks as „taken from a young lava flow", the youngest volcanic products of Brouwer's collection provide no olivine-containing rocks. Besides older lavas and dykes which consisted of leucite basanites (partly transitions to leucite basalts, leucitites and leucite-tephrites) he describes young biotite-leucite-tephrites. As phenocrysts in these are found plagioclase, biotite, augite and a few small leucites, magnetite and apatite. The groundmass contains plagioclase, leucite, magnetite, some augite and volcanic glass.

The biotite content of the Volcanic Mud is higher in 204 than in 203. The Terrigenous + Volcanic Mud 194, 202 and 205, which, as shown in Table 6, belong to the distribution region of the Batoe Tara ash, also vary in biotite and olivine content, in regard to which it must be remembered that owing to the difference in specific gravity the olivine content will decline in ratio to the biotite, during transport, with the increase of the distance from the volcano. The scanty amount of biotite in sample 203 can only be attributed to the differentiation in the young volcanic products, as is proved by the fact that Hartmann found practically no biotite containing rocks of the Batoe Tara, while Brouwer found various biotite-leucite-tephrites. The results of the examination of the deep-sea samples from which this difference in recent volcanic products also appears may therefore be regarded as in agreement with those of both Hartmann (St. 203) and Brouwer (St. 194).

The Batoe Tara ash has scattered more to the east than to the west. Traces of leucite containing glass was found in the sediment 249 and in the Globigerina Ooze 193 as well as in the Volcanic Muds and Terrigenous + Volcanic Muds mentioned above.

It cannot be supposed that west of the Batoe Tara the ash from the volcano has been overlaid by other material, as in samples 317a and 197 Tambora ash is found, while the great eruption of the Batoe Tara took place later than that of the Tambora.

In how far the greater easterly and northerly transport of the material is connected with marine

currents cannot be traced, as in the Banda sea no current measurements have been made below the surface of the sea.

A remarkable phenomenon is that in sample 193 the admixture of volcanic ash from the Batoe Tara is about the same in all layers, down to a depth of 174 cm and amounts to approximately 2%. Here there has been a steady contribution of volcanic ash which can only be attributed to marine currents.

The leucite in the volcanic glass in these samples is also well preserved, but olivine is absent, while the traces of biotite may have another origin. The ash at this spot will not be due to recent eruptions. According to the standard of the rate of settling calculated by Schott (145) for Globigerina Ooze in the equatorial Atlantic Ocean, the settling time for this sample, 174 cm in length, should be estimated at 85.000 years. Here is further argument for the excellent preservative qualities of sea water for many mineral constituents; it may safely be assumed that sediments deposited in the sea are found again in their original form although certain chemical transformations, in this case an exchange of potassium for sodium in the leucite, may occur.

c¹. Terrigenous + Volcanic Mud, containing Batoe Tara ash

As has been said above, the mineralogical composition of the sand fractions of samples 194, 203 and 205 corresponds to that of the Batoe Tara ash, the only foreign component being the hypersthene present in samples 203 and 205. Possibly this may indicate an admixture of material from the Gg. Api, north of Wetar.

The mechanical composition of these samples (fig. 5) is very similar, the fine fractions predominate, the sand fractions contain the highest amount of ash as usual in fraction 50-20 μ.

Röntgenographic examination of clay fractions 5-2 μ and < 0.5 μ of sediment 194B and of the clay casts of the same sample (cf. Chap. VI) demonstrated that clay material and calcite form the principal components, with less quartz, very little muscovite, very little cristobalite and traces of felspar. The composition of the finer fractions, thus, with the exception of the traces of felspar, shows no connection with that of the sand fractions; they are terrigenous components brought from elsewhere. These samples demonstrate very clearly how delusive it may be to deduce the composition of entire sediments of marine deposits from the composition of the minerals in the sand fractions alone.

The bottom layer at 28—55 cm in sediment 194 is of red colour owing to a high iron content. In the röntgenographic examination this occasioned a great darkening of the photograph, so that unfortunately the clay fractions of the upper and lower layers of sediment 194 could not be compared.

d. Volcanic Mud and Terrigenous + Volcanic Mud in the Sawoe Sea

Of the samples raised south of Flores sediment 151 is the only one which comes under the Volcanic Muds. The minerals of this sample, in Table 7, prove to be principally plagioclase, ordinary green augite and yellow to blue green, strongly pleochroitic hypersthene, brown volcanic glass, magnetite and little olivine, accompanied by andesitic rock particles. The ratio of the dark minerals, in which hypersthene predominates, indicates that this material is detritus of basic hypersthene-andesite.

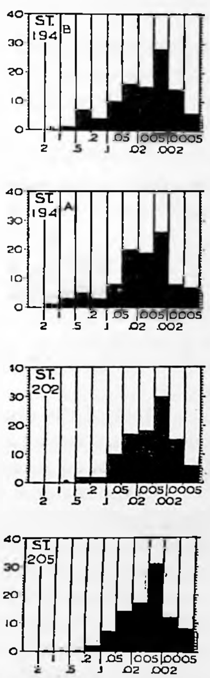


Fig. 5. Mechanical Analyses of Terrigenous + Volcanic Mud, containing Batoe-Tara-ash.

The mechanical analysis in fig. 3 shows an ash curve with a peak in fractions 50-5 μ, the content of volcanic ash in these fractions is higher than in fractions 200-50 μ. Sediment 151, therefore, consists principally of very fine volcanic ash.

The same combination of minerals as in 151 forms the principal component of the sand fractions of sediment 152, the ratio of augite: hypersthene: olivine corresponds to that of 151, but the volcanic ash in 152 has a higher content of andesitic grit and heavy minerals and a lower content of glass; in correspondence to this the ash (fig. 6) proves to be more coarse-grained; its peak is in fraction 100-50

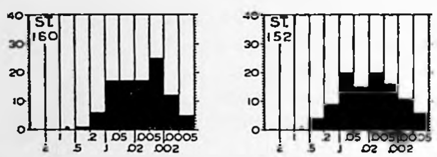
TABLE 7. Mineralogical Composition of Volcanic Mud and

No.	Fr.	rock particles and pumice	plagioclase I	plagioclase II	quartz	volcanic glass	augite	hypersthene	olivine	green hornblende	red hornblende	actinolite	biotite	muscovite	chlorite	apatite	epidote	titanite	garnet
151	1																		
	2					0,2													
	3					0,1													
	4	7	10			14	1	3	0,2				0,2						
	5	16	25			18	2	5		tr.									
	6										tr.								
152	2	†																	
	3	33	16			7	1	3	0,2				0,3						
	4	49	23			7	3	6	0,1	1			0,2						
	5	40	31			7	2	5	tr.	2	tr.		0,1		0,1	tr.	tr.		
	6					25													
380	P	†	†	†	†	†	†	†		†		tr.	†		†	†	†		tr.
381	S	††	††			†	†	†	tr.	†									
160	2	†																	
	3	4	tr.	tr.	tr.	10		tr.		tr.									
	4	30	9	2	tr.	16	0,5	0,5		0,5			tr.	0,2					
	5	33	22	3	2	10	1,5	2		1	tr.	0,5	0,5	0,2	0,2	tr.	1	0,5	tr.
	6																		

μ. It is possible, therefore, that 152 lies nearer to the volcano from which the ash is derived; presumably this volcano should be sought in Flores.

On Flores there are ten active volcanoes, according to the Netherlands Indies Volcanological Survey of 1936.

The volcanoes of Flores have been described by Kemmerling (88). Of the still active ones, situated in mid Flores, which come into consideration, the material of the Inië Lika proves to be little distributed. From the Inië Rië only slight activity has been known in historical times. The remaining four, namely Amboe Romboe or Keo Piek, the Goenoeng Poei or Medjah, the Goenoeng Ija and the Keli Moetoe are all composed of basaltic hypersthene-andesite, or hypersthene-andesite and hypersthene-basalt.



Fi.g 6. Mechanical Analyses of Terrigenous + Volcanic Mud in the Sawoe Sea.

Most of the eruptions of the Gg. Ija, lying on a peninsula to the south of Endeh, have been noted; there was a particularly violent one in 1844. Violent eruptions of the Keli Moetoe and the Keo Piek are not so accurately known.

As the material of the Flores volcanoes is all so similar it cannot be ascertained which of them has provided the material of samples 151 and 152. Nevertheless it may be ascertained that the volcanic ash was especially dispersed in a westerly direction as in sample 151, marked as ,,large", a very considerable amount of volcanic ash is found.

Sediment 152 has been classified amongst the Terrigenous + Volcanic Muds, as (compared to sediment 151) the lower fraction 50-20 μ and the lower content of volcanic glass indicate a small content of *fine* ash, while the peak in the fractions 20-5 μ resembles that in the Terrigenous Muds 153 and 155, which samples taken to the south of Flores, contain very little volcanic ash.

The two peaks in the mechanical analysis of sample 152 would then be explained by two kinds of material being mixed, namely volcanic ash with a chief fraction of 100-50 μ and Terrigenous Mud with a highest fraction of 20-5 μ. The considerable admixture of terrigenous material is somewhat indicated by the minerals in the sand fractions, namely by the presence of altered biotite*) and epidote, by a very small portion of the rock particles having a weathered appearance and in the hyper-

*) A small amount of altered biotite occurs also in sediment 151.

zircon	magnetite and ilmenite	pyrite	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Alcyonarian spicules	calcareous Sponges	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
			99	99													1	0,6
			95	95,2	4,5	0,3						4,8						2,6
			85	85,1	14	0,9						14,9						2,9
			40	75,4	19	0,6						19,6	1	4		5		5,3
	4	tr.	4	74	20	1			1	0,5		22,5	2	1		3	0,5	13,5
		1	2	72					2			22	4	1	1	6		27,5
			†		†	†												0,1
			27	87,5	11	1						12		0,3		0,3		3,7
			6	95,3	4							4	0,2	0,5	tr.	0,7		9,2
	4		2	93,2	4						0,3	4,3	1,5	1		2,5		20,3
		3	2	75								17	4	1	1	6	2	14,6
	†	†	†		†	†	†			†	†		†	†	†			
	†				†	tr.					†							
			†		†		†						†					0,2
			10	24	67	5	tr.					72	4	tr.		4		0,5
			4	63	25	3	1	tr.		1		30	4	3		7		6,4
0,5	3	tr.	3	84	9	1			tr.	1	3	14	2	tr.		2		16,7
		0,2	2	82,5								10	5	1	1	7	0,5	17,1

sthene a few ragged specimens are found. The green hornblende, although little affected, should probably be regarded as a terrigenous component in this case, derived from not recent, but little altered volcanic products, as the content here is higher than in the basic pyroxene-andesites of Flores.

South of east Flores lie stations 381 and 380. The small sample raised near the coast, 381, is sandy; it contains much rock grit and very little volcanic glass; the content of green hornblende, in contrast to sample 380, is considerable. The minerals are partly fresh, the plagioclase is sometimes zonal and some of the minerals are slightly altered.

In the preparation of sand fractions of sample 380 slightly turbid quartz, actinolite, biotite, chlorite, epidote and garnet were found as well as fresh minerals of volcanic origin.

Both samples contain recent volcanic material, derived from the Lobetobi Laki Laki and the Lobetobi Perampoean, perhaps also from the Keli Moetoe, or it may have been transported by the rivers off the Gg. Egon, as all these volcanoes are composed of basic pyroxene-andesites to basalts. The comparatively large content of green hornblende in 381 indicates an admixture of not recent, thus terrigenous material in this sample, derived from basic volcanic rocks. The terrigenous admixture in 380 is comparable to components of the terrigenous sediments lying more southerly in the Sawoe sea. No indications were obtained of the ratios of the constituents of this sample, which is 18 cm thick.

The mineralogical composition of sediment 160, lying to the south of the island of Lomblèn shows both recent volcanic and terrigenous components. The rock grit is partly fresh andesite, and partly altered to brown products. The augite is pale green or green, practically non-pleochroitic and partially idiomorphic like the hypersthene and hornblende. The hornblende is pleochroitic from greenish brown to brown, the hypersthene from yellow to greenish blue. Partly altered hypersthene also occurs with pleochroism from pinkish yellow to green; roze coloured hypersthene was never found in this research amongst recent volcanic rocks. The quartz is partly clear, containing air bubbles, and partly clouded.

The mechanical analysis of 160 (fig. 6) shows a predominance of terrigenous components; the content of recent volcanic ash may be estimated at some 25%. The terrigenous components may be compared to those of the Terrigenous Muds in the Sawoe sea.

The origin of the recent volcanic material is uncertain. The recent volcanoes in the neighbourhood are the Ili Boleng on the island of Adonara, the Ili Lewotolo in the north west of Lomblèn, the Ili Labelekan and the Ili Weroeng in the south of Lomblèn, and the Siroeng in the south of the island of Pantar.

The recent volcanic rocks of the Ili Boleng on Andonara, as reported by Brouwer (27), are olivine-basalts and pyroxene-andesites. The olivine-basalts are composed of basic plagioclase, augite, olivine, iron ore and volcanic glass; the pyroxene-andesites consist of basic plagioclase, augite, hypersthene, iron ore and glass, the augite content usually being greater than the hypersthene content.

Concerning the rocks of the Ili Lewotolo and the Ili Weroeng on Lomblèn Hartmann (70) states that in both basalt predominates, while much less basic pyroxene-andesite was found as well. Moreover in the products of the Ili Lewotolo one hornblende-andesite was found and from the Ili Weroeng gabbroic and quartz-dioritic inclusions were collected. In the rocks of the Ili Labelekan Hartmann found an equal amount of basalts and basic pyroxene-andesites.

Brouwer (27) describes olivine-basalt to trachybasalt from young lava flows of the volcano Lewotolo, composed of much basic plagioclase, augite, olivine, iron ore and much brownish glass, while felspars rich in alkalies are also found; and a pyroxene-andesite to trachyandesite which contains all these minerals except olivine, with moreover little hypersthene and some small crystals of amphibole.

Verbeek (168) described the youngest products of the Siroeng on Pantar as basalt and the older rocks as pyroxene-andesites, while Hartmann (71) found both basalts and andesite-vitrophyres on the Siroeng volcanic cone.

Periods of violent eruptive activity are not known in the Ili Boleng, the Ili Labelekan and the Siroeng. Hartmann states, however, that products of the Labelekan came down the slopes on the south into the deep Sawoe sea. He makes the same assumption for the steep southern slopes of the Siroeng mountains, where lava flows fall into the sea. A few eruptions are known of the Ili Lewotolo, the most violent of which was in 1852. The Ili Weroeng was in violent eruption in 1870, when enormous quantities of ash, lapilli and bombs were thrown out from the Ado Wadjoeng crater. In 1928 lava was forced out of this crater and in the Ado Wadjoeng area 40 cm fresh ash fell.

On map I, in connection with these eruptions, an area of Volcanic Mud is diagrammatically represented around the Ili Weroeng.

The volcanic material in sample 160 is probably derived both from the slopes of the Ili Labelekan and from the ash eruptions of the Ili Weroeng.

The area of Terrigenous + Volcanic Muds in map I is continued south of the small Soenda islands to round the Siroeng volcano on Pantar.

e. Volcanic Mud, derived from Goenoeng Api north of Wetar

The Gg. Api, north of Wetar is described by Verbeek (168) in his Molukken report (p. 570—571) as a very small uninhabited island, consisting of one volcanic mountain estimated at about 275 m height. The volcanic mantle consists largely of lava; on the north side and the broken south west side loose ejections lie upon the lava. Verbeek collected rocks from the lava of the north side, both of which consisted of pyroxene-andesite, containing as phenocrysts much plagioclase, hypersthene and biotite, little augite, magnetite and brown dusty apatite, and some olivine. The groundmass consisted of usually colourless glass, locally brown in colour, with microlites of plagioclase, pyroxene and ore.

Kuenen (99) visited the Gg. Api north of Wetar during the Snellius-expedition. He recounts that „the echo soundings in the surroundings prove that this volcano rises up near on 5000 m above its original base". He points out that „although the cone rises only 282 m above sea level it is nevertheless one of the highest, perhaps the highest volcano of the entire East Indian Archipelago". He collected rocks from the crater and the west coast. They are all pyroxene-basalts with the same minerals as Verbeek found. The relative amounts vary considerably. Thus one sample was comparatively rich in olivine, while in the others it only forms part of small inclusions together with some plagioclase, pyroxene and ore. Sometimes the hypersthene predominates over the augite, sometimes it is the other way about. The biotite was generally an accidental component. These variations were most obvious in a conglomerate tuff showing almost as many types as there were inclusions in the slide.

The mineralogical composition of samples 245 and 246 (table 8) collected at approximately 20 km and 30 km distance from the Gg. Api corresponds in the rocks described by Kuenen and Verbeek; the ratio of the dark minerals in these sediments corresponds better to the rocks which Kuenen describes from the crater and western slopes, and which probably represent the recent eruption products.

The minerals are idiomorphic, only amongst the biotite besides the idiomorphic six-square flakes there are some „bleached" specimens. The biotite is mostly strongly pleochroitic from yellow to red, conspicuous by a comparatively large axial angle; faintly pleochroitic green-brown biotite also occurs. The various minerals are perceptable in the rock particles so that it is certain that the biotite is not of terrigenous origin but a part of the andesite.

Of sediment 245 the layers 5—10 cm (245A) and 10—15 cm (245B) have been sampled. The

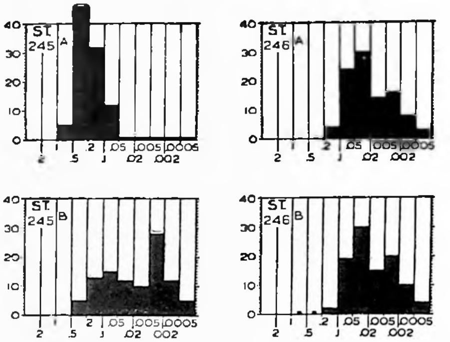
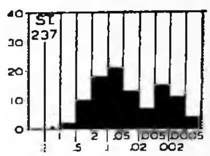


Fig. 7. Mechanical Analyses of Volcanic Mud, derived from Goenoeng Api North of Wetar.



Mechanical Analysis of Volcanic Mud, derived from Seroea Volcano.

mechanical analyses in fig. 7 show that the layer of 5—10 cm consists of volcanic sand with a principle fraction of 0.5—0.2 mm; layer 10—15 cm, which is of the same mineralogical composition consists of volcanic ash with a peak in the fraction 100-50 μ and a considerable number of clay fractions. A temporary great activity of the Gg. Api accounts for the layer of volcanic sand at 5—10 cm depth in the sediment. This layer must have been rapidly deposited, as it contains practically no clay particles.

Sample 245B contains sporadic fragments of leucite-containing glass, as known from the Batoe Tara.

Samples 246A and 246B represent the layers 0—10 cm and 70—79 cm of a 79 cm long sample; they display practically the same mineralogical and mechanical composition as is shown in Table 8 and fig. 7. The volcanic ash in this sediment is slightly finer in grain than in 245B. The ash content in both layers amounts to $\pm$ 60%. The ash layer at St. 246 is thus of considerable thickness, which is not surprising, as the Gg. Api north of Wetar must have built itself up from a depth of 5000 m and is therefore a large volcano, which will have scattered a great deal of material during its formation.

No reliable estimate could be formed of the extent of the distribution of the Gg. Api material. In the Terrigenous + Volcanic Mud 249 there must be a portion of Gg. Api material, considering the ratio of idiomorphic augite, hypersthene and biotite and the presence of these minerals with plagioclase in the andesite particles. The ash content of the sample is low. Presumably Gg. Api material is also contained in sample 241A, in which the ash content is likewise low (see fig. 8).

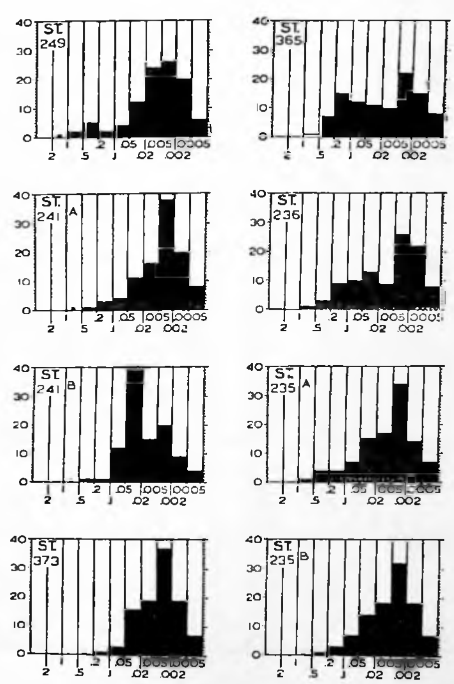


Fig. 8. Mechanical Analyses of Terrigenous + Volcanic Muds in the Central and the Eastern Banda Sea.

Sediments 241 and 373 lie at places where the

TABLE 8. Mineralogical Composition of Volcanic Mud and of Terrigenous + Volcanic

No.	Fr.	rock particles and pumice	plagioclase I	plagioclase II	quartz	volcanic glass	augite	hypersthene	olivine	green hornblende	red hornblende	actinolite	biotite	muscovite	chlorite	apatite	epidote
245A	2	91	5				2	0,5					2				
	3	78	16				2	1	tr.				3				
	4	66	21				4	4					4				
	5	41	37			2	6	5	2				3			0,5	
	6																
245B		††	††			†	†	†	†				†			†	
246A	2	†	†			†											
	3	†	†			†											
	4	35	7			17	1,5	4	0,5				13				
	5	35	19			21	3	5	1,5				5				
	6	25	18			25	2	3	0,5	0,2			4				
246B		††	††			††	†	†	†	tr.			†				
249	1		2			18											
	2		1			1		0,2									
	3		0,1			0,2	0,1	0,1									
	4	0,2	0,3	0,1		0,6	0,1	tr.		tr.			0,1				
	5	4	10	0,5	tr.	5	0,3	0,3		0,1		0,1	0,3	1			0,1
	6																
241A	2																
	3																
	4	0,3	0,2														
	5	20	11	1		4	1,5	1,5		0,3	0,1	0,2	1		0,5		tr.
	6	5	27	1		5	0,6	1		0,5	0,2	0,2	0,5	1	2		tr.
241B	2																
	3	5	2			40											
	4	5	1			50											
	5	13	5			66	1	0,5		1	tr.				tr.		
	6	7	6			71	0,5	0,3		0,5			tr.				
242	5	14	4			6	1	1	tr.	0,1			tr.		1	tr.	
373	3	2				10								tr.			
	4	4	2	tr.		8	0,2	tr.					0,1	0,5			
	5	10	15	tr.		12	2	2		1			0,1				
	6											tr.					
237	1	†															
	2	50	1			1	1	1									
	3	59	8			0,5	3,5	5									
	4	48	14			3	4,5	9	tr.								
	5	31	24			4	4	8		tr.							
	6	21	25			5	1	2									
365	2	90	3				2	2									
	3	75	7			1	6	6									
	4	50	15	0,2		3	5	9	0,2								
	5	40	19	4	0,2	3,5	6	12	0,2	0,1							tr.
	6	14	16	8	3	8	1,5	3					1	2			
236	2	11	3			50											
	3	23	25			13	4	8									
	4	21	14			9	3	5									
	5	22	20			9	3	4		tr.							
	6	12	16			11	0,5	1		tr.							
235A	2	3				16											
	3	7	3			5											
	4	21,5	15			7	1	4									
	5	21	16			18	1	3					1		1		
	6													1			
235B	2	4				4											
	3					1											
	4	21	6			13	0,5	1	tr.	tr.							
	5	25	28			14	3	6		tr.			tr.		1		
	6			tr.	tr.									2			
320	5	7	6			5	0,5	1									

zircon	magnetite and ilmenite	ferro manganese oxides	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
					100												5,2
					100												46,0
	0,5				99,5								0,5		0,5		32,2
	3				99,5								0,5		0,5		12,1
					90					0,5	0,5	1	7	0,5	8,5	1	1,0
	†			†		†				†		†	†	†			
				†		†											0,1
				†		†											0,1
				7	85	4					4	tr.	11		11		4,0
	0,5			2	92	5				1	6	0,5	1,5		2		24,4
	0,5	2	0,2	0,6	81	2				5	7	1	10	1	12		30,3
	†	†		†		†				†		†	†	†			
				80	100												0,4
				82	84,2	15	0,8				15,8						1,9
				62	62,5	31	1				32	0,5	5		5,5		4,7
	0,1		0,5	60	62	27	1				28		10		10		2,1
	0,3		0,5	45	67,5	29	1				30	0,3	2		2,3	0,2	3,6
				17	75						15	3	6	0,5	9,5	0,5	11,6
				100	100												0,2
				100	100												1,3
				95	95,5	0,2					0,2	0,3	4		4,3		3,1
tr.	0,5			47	88,6	2			1,4		3,4	4	4		8		4,0
	0,5			38	82,5	1			4		5	2	8	2	12	0,5	11,4
						†											0,1
				25	72	14	tr.				14		14		14		0,5
				12	68	3					3		29		29		0,7
	1			3	90,5	5		tr.		1	6	0,5	3		3,5		12,0
	2			2	89,3	2				5	7	0,7	2	1	3,7		39,1
				2,9	30	—63—		tr.			63	4	3		7		7,3
			1	66	79	8					8	4	8		12	1	0,4
			0,1	40	55	18	tr.				18	3	24		27	tr.	0,7
			0,9	18	61	—30—					30	3	6		9	tr.	2,9
				5	68						20,5	4	6	1	11	0,5	15,5
																	0,1
					54	45				1	46						1,5
					76	23				1	24						9,6
	0,5			tr.	79	20				1	21		tr.		tr.		17,5
	2				73	23				2	25	1	1		2		20,9
	1				55	23				18	41	0,1	3,9	tr.	4		13,4
				3	100												0 9
				4	99								1		1		7,3
				11,6	94								6		6		14,7
	2			10	97							1	2		3		12,1
	1			20	77,5							3	17	2	22	0,5	10,6
				3	67	32	1				33						0,5
				tr.	73	27					27						3,3
				1	53	39	1	1			41		6		6		8,7
	2			1	61	35	1				36	1,5	1,5		3		9,6
	1			2,5	44	14	1			28	43	2	9	2	13		13,1
				80	99	1					1						0,6
				80	95	1					1		4		4		3,5
	0,5			38	87	0,9	0,1				1		12		12		3,5
	2	2		20	85	2,7	0,3			2	5	1	9	tr.	10		7,1
		3		15	74					2	2	2	20	2	24		14,6
					8	92					92						0,4
				48	49	50					50		1		1		0,6
	tr.			22	63,5	25	1				26	0,5	10		10,5		3,3
	1			7	85	10,5	0,5			1	12	0,5	2,5		3		7,0
				8	70,5	4				10	14	2	12	1	15	0,5	14,0
	tr.			0,5	20	80	tr.		tr.		80	tr.	tr.		tr.		18,5

area of distribution of the ashes of the Gg. Api north of Wetar, the Woerlali on Damar and of the volcano Téon may overlap each other.

Samples 241A and 241B, the upper layer of 0—40 cm and the lower layer of 40—80 cm respectively from St. 241, present a clear picture of the varying composition of the sediments in the regions where volcanic and terrigenous material are mixed.

As fig. 8 and Table 8 show, the lower layer consists principally of volcanic ash, with a peak at fraction 50—20 μ, which has a high glass content. The augite is pale green; the hypersthene is faintly pleochroitic from yellow to green; these light colours in the pyroxenes and the predomination of augite make it probable that the ash is derived from the Woerlali on Damar.

Molengraaff (113) gives a corresponding description of these minerals in an olivine-containing pyroxene-andesite from the Woerlali; what he calls small, often resorbed olivine crystals are not found in 241B, there is a small hornblende content. Wichmann (183) describes some hornblende-containing rocks from Woerlali. Verbeek (168) encountered olivine-free pyroxene-andesites amongst the older volcanic products on Damar.

No eruptions of the Woerlali have been described. As the ash layer is found under a 40 cm thick layer rich in clay, it must have been deposited long ago. In this case also, the habitus of fresh volcanic ash was preserved.

The upper layer 241A, rich in clay, contains but little volcanic ash. This ash differs from 241B by having a much lower glass content and as augite does not predominate over hypersthene it shows a great resemblance to the ash in sediment 246, although no olivine was demonstrated in it. An admixture of volcanic ash, derived from the Woerlali or from Téon is not impossible, considering the position of St. 241.

As shown in Table 8, the fine sand fractions of sample 241A show small quantities of minerals of terrigenous origin, in contrast to fraction 5-2 μ, which, according to the röntgenographic analysis, consists practically entirely of terrigenous material, for the half of quartz and muscovite and the rest of clay minerals and a few calcium carbonate (see Chap. VI). In the fractions finer than 2 μ the percentage of clay minerals increases.

In sediment 241, therefore, we have a 40 cm thick layer of terrigenous deposit with an admixture of a little volcanic ash lying upon a Volcanic Mud of which the ash is differently composed to that of the upper layer.

Sample 373, representing a 6 cm thick upper layer of the sediment, resembles 241A in mechanical composition. The mineralogical composition resembles to some extent that of 241B, the augite and the hypersthene are light coloured in the same way, but the glass content is much lower. Probably the volcanic ash in this sample is also derived from the Woerlali; the great discrepancy in the glass content may be due to a difference in the period of eruption or to the material having been transported by marine currents.

The Globigerina Ooze from St. 242 contains fully 5% volcanic ash, the sample is 57 cm thick. Both light and dark green augite are contained in it. The station lies nearest to the island of Damar, but the sediment seems to contain different kinds of volcanic ash (material from Woerlali and the Téon, perhaps).

f. Volcanic Mud and Terrigenous + Volcanic Mud containing Seroea ash

Sample 237, taken north of Seroea, as the mineralogical composition in Table 8 and the mechanical analysis in fig. 7 show, consists of some 50% volcanic ash with the peak in fraction 200-50 μ. The minerals are idiomorphic, the composition is that of pyroxene-andesite in which hypersthene predominates as heavy mineral. The low content of volcanic glass with the high amount of heavy minerals and undisintegrated andesite particles, together with the coarse grain of the ash, form a clear indication that the volcano from which the material is derived cannot be far distant. The nearest active volcano is that on the volcanic island of Seroea, the distance of which from St. 237 being some 30 km. The distance from the more westerly volcanoes of Nila, Téon and Damar is about 100, 150 and 200 km respectively and from Bandi Api, lying to the north, 200 km. These distances are so great that, comparing it with the mechanical composition of ash from the great Tambora eruption deposited at similar distances, it seems impossible that the ash in 237 could be derived from any of these volcanoes.

At the same time, however, the description of the rocks of the five above mentioned volcanoes does not directly indicate that the ash in sample 237 is derived from the Seroea. A comparison of the composition of these rocks is given below.

The rocks of the Woerlali on Damar have already been enumerated, they are principally pyroxene-andesites in which augite predominates as heavy mineral and which contain a little biotite and hornblende and sometimes a small amount of olivine.

The younger rocks of the Banda Api are composed of olivine-containing pyroxene-andesite. Verbeek (166) describes as phenocrysts in a bomb from the crater: plagioclase, augite, less hypersthene, olivine and iron ore.

Verbeek (168) examined a sample of lava flow from the west coast of the island of Téon, a single volcano, 775 m high. He describes it as pyroxene-andesite with a great deal of felspar and pyroxenes, without olivine and with light brown glass in the microlitic groundmass.

The island of Nila, as reported by Verbeek (168), consists of an older rim of lava and a younger eruption cone, the Kokon, chiefly composed of loose ejections. He only examined a sample taken on the north west side of the old wall, which consisted of finely porous pyroxene-andesite, without olivine, and with brown, colourless glass. In the groundmass much augite and iron ore is found. Nothing is known of the younger eruption products.

Seroea is described by Verbeek (168) as an eruption cone, 650 m high, flattened at the top, surrounded by an older rim of lava and breccia. A sample of the old rim, taken on the north west side consisted of pyroxene-andesite with a great deal of hypersthene and less augite, without olivine. A sample of the northern recent lava flow, which runs eastwards from the large cone, was non-porous olivine-containing pyroxene-andesite with a small amount of yellowish green olivine. It is not clear whether hypersthene predominates as heavy mineral in this sample.

In Kuenen's (99) opinion the island of Seroea does not appear to be an „older rim" around a „younger cone", but a north west to south east row of eruption points, one of which has been built up to the present central cone. He could find no support of Verbeek's statement that young lava flows occur on the north east slope. The rocks from Seroea which Kuenen examined contained no olivine and did not otherwise differ from what Verbeek had collected.

According to the description of the rocks, the material in sediment 237 cannot be derived from the Woerlali or the Banda Api. The description of the rocks from Téon, Nila and Seroea is not sufficient to justify the conclusion that the ash in 237 is derived from the Seroea, a conclusion which could only be based upon the presence of traces of olivine in the sample.

Recent violent eruptions are known of both, Téon and Seroea. Wichmann (181) points out that the tremendous eruption of the island „Teeuw", described by Rumphius, must have taken place on Téon. This was in the years 1659, 1660 and 1663. In 1693 and 1904 smaller eruptions took place.

Verbeek (168) in his Molukken report, enumerates eruptions of the Seroea in 1683, 1687, 1693 and 1844. He considered that the two lava flows, lying east from the principal crater, which are almost bare of vegetation and looked very new at the time of his visit in 1899, are due to the eruption of 1844. Taverne (158) who communicated the news of the activity of the Seroea in September 1921 points out that the eruptions have been very superficially described and that none of the descriptions mention anything about showers of ash. The most violent eruption seems to have been that of 1693, in which a great part of the mountain was shattered and plunged into the crater, almost the whole island was converted into a sea of fire, being covered by glowing and melted lava *).

Of the Kokon on Nila only faint activity in 1903 and 1932 is known (32).

As regards volcanic activity, therefore, both Téon and Seroea might have contributed the ash to sample 237.

A comparison of the minerals in the volcanic ash of 237 with those of the Terrigenous + Volcanic Muds 365, 236 and 235 shows that the ash in 365 is of the same mineralogical composition as 237, that it is also coarse-grained (fig. 8) with a high content of heavy minerals and a low content of light ones, while the olivine content is somewhat higher than in 237. This sample, therefore, taken to the east of Seroea, displays a composition, corresponding to that of the recent lava flow sampled by Verbeek. The ash content of this 16 cm thick sample amounts to 35 to 40%.

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*) Quoted by Junghuhn.

TABLE 9. Mineralogical Composition of Volcanic Mud and Terrigenous

No.	Fr.	rock particles and pumice	plagioclase I	volcanic glass	augite	hypersthene	olivine	green hornblende	red hornblende	actinolite	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	titanite	magnetite and ilmenite
345	2			†													
	3	12	4	55	tr.	tr.											
	4	28	10	44	0,5	1		0,1				tr.	tr.				0,3
	5	18	18	50	0,6	1	tr.	0,3	0,1				tr.	tr.	tr.		2
	6																
344	2			25													
	3	12	8	22	0,3	1											
	4	15	7	40	1	2,5	0,2	tr.									2
	5	15	8	40	0,5	1	tr.	0,5	tr.	0,1		tr.	0,5				2
	6										tr.						
347B	1			†													
	2	20		25													
	3	20	15	12		2	0,2	4									
	4	20	11	16	0,3	1	tr.	1									1
	5	32	19	20	1,5	3	0,2	3	0,2				0,1	0,1			2
	6																
347C	2	30		13													
	3	42	7	21			0,5										
	4	8	2	14	0,2	0,2	0,1	tr.									
	5	35	19	28	0,7	2	0,1	1			tr.						2
	6									tr.							
347A	1			†													
	2	15	4	70	tr.												
	3	40	12	30	1	0,5	0,5										0,1
	4	20	12	20	2	1,5	0,4										0,1
	5	27	18	32	2	2	0,1	1	tr.		0,3		0,1	tr.			1
	6																
346	P	††	†	†	†	†		†	tr.								†
283	1—5	†	†	†	†	†		†	†				†				†
284	2																
	3	2	2	5				tr.									
	4	10	4	10	0,3	0,1		0,3	tr.		0,1		0,5				
	5	30	13	15	6	2		2	1	tr.	0,2		3	0,2	0,1	tr.	7
	6																

Samples 236 and 235B, in which no olivine is shown, have the same ratio of augite to hypersthene as 237 and 365. The content of andesite particles and heavy minerals in the ash of 237 is greater than in 236 and in 236 than in 235B. The volcanic ash is coarsest in 237 and finest in 235. This corresponds to the position of the stations with relation to the Seroea; the distance from it being for Sts. 237, 236 and 235, 30, 50 and 135 km respectively. The distance from Nila is 100, 100 and 160 km, from Téon 150, 145 and 185 km. It is therefore probable that the ash in samples 237 and 236 is derived from the Seroea, while for sample 235B this may also be assumed, considering the similar mineralogical composition. The sampled upper layer of 0—10 cm i.e. 235A, shows a still higher ratio of hypersthene to augite than the samples just discussed; the origin of the ash is uncertain. It is remarkable that both in 235A and in 235B the ash content per sample amounts to some 20%. In the 65 cm long sample 236 the ash content is somewhat higher. The mineralogical examination of the sand fractions indicates the presence of terrigenous components in samples 365 and 235, but not in 236.

The Globigerina Ooze 320 contains some 10% volcanic ash of similar composition to that in 237. The distribution region of material from the Seroea is therefore of considerable extension.

No estimate could be formed of the distribution of material from the volcanoes on the islands of Damar, Téon and Nila, although ash from the Woerlali was found in a few Terrigenous + Volcanic Muds. On Map I, therefore, the presence of Volcanic Mud is diagrammatically represented by circles, the same as with the volcanic islands of Paloeweh, Sangean Api and Banda Api.

For the Banda islands the Volcanic Muds, collected by the Challenger-expedition, C 194 and C 194A were also taken into consideration, of these it was stated that ,,in the dredge were several

+ Volcanic Mud near Halmaheira

pyrite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Coral debri	calcareous Sponges	calcite	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
				†												0,05
		2	73	24,5	0,5					25	2			2		0,3
		4	88	10						10	1	1		2		0,8
		2	92	6	0,3			tr.		6,3	1	0,2		1,2	0,2	19,7
		1	96							3	0,5	0,2	0,1	0,8	0,2	41,0
			25	75						75						0,7
		tr.	43,3	56	0,7					56,7		tr.		tr.		9,6
			67,7	31	1					32	0,1	0,2		0,3		5,1
			67,6	29	1					30	2	0,5		2,5		17,4
		tr.	61							34,5	3	1	tr.	4	0,5	23,1
		†														0,15
		47	92	7,9	0,1					8						0,65
		35	88,2	6,5	0,3					6,8	1	4		5		5,6
		25	75,3	—14,5—						14,5	1	9	0,2	10,2		2,3
0,1		5	86,2	—10,7—				0,1		10,8	2	1		3		13,0
0,3		2	85							9	3	2	0,5	5,5	0,5	34,5
			43	52	3	2				57						0,2
			70,5	26	2	0,5				28,5		1		1		0,3
		5	29,5	28	2,5	1				31,5	3	33	2	38	1	0,9
0,5		1	89,3	6	1	0,2				7,2	2	1	tr.	3	0,5	11,6
3		tr.	80							10	5	3	1	9	1	32,2
						†										0,15
			89	8	tr.	3				11						1,4
			84	11	tr.	2				13	tr.	3		3		3,6
		2	58	--17,5—		0,5				18	2	20	1	23	1	1,2
0,5		2	86	---9,5--		tr.		0,5		10	2	1	0,5	3,5	0,5	12,9
4		0,5	74,5					0,2		14	6	4	1	11	0,5	28,3
							†		tr.							
										††	†					
				†	†						†					0,1
		4	13	75,5	0,5	tr.				76	3	8		11		0,9
tr.		6	31,4	55	0,3	0,3				55,6	3	10		13	tr.	1,6
tr.	0,5	3	83	12,6	0,1					12,7	4	0,3		4,3		8,8
0,3		1	77						tr.	12	6	4	0,5	10,5	0,5	20,8

fragments of volcanic rocks and pumice, measuring from 1 to 4 inches, Corals, siliceous Sponges and calcareous Algae".

Sediment 358, north of the Banda Api is classified among the Terrigenous + Volcanic Muds, although it consists chiefly of terrigenous material and also of minerals of terrigenous origin; besides this there are, however, coarse, colourless and dark particles of pumice with a few minerals which compose volcanic ash. These minerals are idiomorphic plagioclase, augite, hypersthene, some hornblende and volcanic glass. Augite is the principle dark mineral. This ash is probably derived from the Banda Api.

The coarse layers in the part of sample 358 that was examined, consist remarkably enough, for only a small part of recent volcanic ash and pumice, the greater part of these layers is formed of mica schists and detrital products of these and other crystalline schists. It is not clear why here alternating layers of coarse and fine material of a similar composition have been deposited.

The sediment will be further discussed with the Terrigenous Muds in connection with sample 360.

The presence of small quantities of volcanic ash from the Banda Api in an area to the west of the volcano is indicated by a pink line on Map I.

g. Volcanic Muds near Halmaheira

West of north Halmaheira and of the volcanic islands of Ternate, Motir and Makian, an area of Volcanic Mud is shown in which samples 344, 345 and 347 lie. Table 9 shows that volcanic ash forms the principle component of all these samples; they all possess a considerable content of vol-

canic glass, it being highest in 345. The glass content of the volcanic ash in both 344 and 345 amounts to about 60% (the mineralogical analysis of 344A is absent as I did not receive this sample). Table 9 shows that the volcanic material of 344 and 345 has the composition of hypersthene-andesite. In the andesite particles plagioclase, hypersthene, augite, green hornblende and olivine occur. They are ordinary green augite, yellow to blue green, strongly pleochroitic hypersthene and moderately pleochroitic green hornblende. The volcanic glass is porous, often exhibiting flow structure and may be either brown or practically colourless. The composition of sample 347C is about the same as 344 and 345, but the glass content of 347C is lower i.e. about 35%. As this sample is taken at 80—86 cm depth in the sediment it does not seem likely that it is derived from the same eruption as the superficial layer in 344 (0—30 cm) and 345 (5—10 cm), although it may come from the same volcano. The ash in sample 347B and 347A is of a different mineralogical composition.

The mechanical analysis in fig. 9 shows that sample 345 has an almost purely ash curve with a peak in the fraction 50—20 μ, the clay content being low. The other samples have a higher clay content, especially sample 347C.

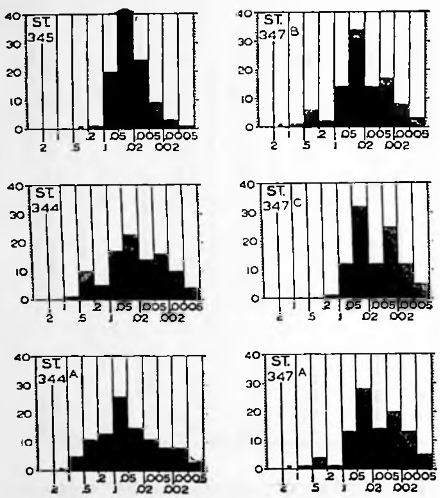


Fig. 9. Mechanical Analyses of Volcanic Muds near Halmaheira.

Little is known concerning the volcanoes of Halmaheira, the Doekono, the Iboe and the Gamkonora, lying on the northern arm.

The *Doekono*, according to Wichmann (177) was in eruption in Nov-Dec. 1550. Hueting (80) records slight activity in 1901. The Volcanologic Survey (33) reports that the activity has increased since 1933.

Verbeek, in the Molukken Report (p. 262) describes rocks from a lava flow called „Batoe angoes" on the shore near Galela, a flow which Gogarten (61) believes to come from the Doekono. These rocks were augite-andesite rich in glass, composed of plagioclase, augite, iron ore and a great deal of dark brown glass, and a similar rock in which there were moreover a few olivines. Gogarten examined some rocks from the same lava flow and from another recent flow proceeding eastwards; he styled these rocks basalts, as he found a good deal of olivine in them and only local streaks that were free of olivine. In fine-grained tuffs from the Doekono or Tolo, however, he again met with no olivine. According to Stehn the new lava flow of 1933 consists of augite-hypersthene-andesite.

The only eruption known of the *Iboe* is, according to Gogarten, a mild one at the end of Aug. 1911. No rocks have been described from this volcano.

Wichmann (179) records that the first known eruption of the *Gamkonora* took place in 1564 or 1565. There was a celebrated ash eruption on the 20th May 1673, which was accompanied by a violent earth and sea quake. The ashes were carried as far as Menado on Celebes and to the Sangi islands, Mindanao and Ternate. According to Gogarten in the 19th century clouds of smoke were frequently seen ascending from the Gamkonora, which were plainly visible from Ternate. Some activity was reported in 1926.

No rocks have been described from the Gamkonora.

West of Middle-Halmaheira lie the volcanic islands of *Ternate, Motir* and *Makian*, which have displayed recent activity.

The *Peak of Ternate* has been most frequently examined. Wichmann (179, 183) has enumerated some 100 eruptions between 1608 and 1898, the list is supplemented by Gogarten (61) and Kemmerling (85). The activity has never caused much damage, as Taverne (159) reports, except in 1773 and in 1840, the last catastrophe, however, was chiefly attributed to a violent earthquake. The distribution of material from the Peak of Ternate, in spite of the large number of eruptions, can only be of a limited range in recent times.

Rocks from the Peak of Ternate were first described by Renard (126); he found augite-andesites and basalts. Retgers (127) has described 5 pyroxene-andesites and one basalt, amongst these were a pyroxene-andesite from „Verbrande Hoek", the lava flow of 1737, which contains both augite and hypersthene. Verbeek (168, p. 252—253) found basalts, olivine-containing and olivine-free pyroxene-andesites. There were fragments from the eruption of 1897 which were of olivine-free pyroxene-andesites with brown glass. The chief pyroxene is augite. Brouwer (15) describes the oldest rock of the lava from the oldest crater wall as augite-hypersthene-andesites. The lava of the inside slope of the middle crater consists of augite-andesite without hypersthene. The products of the latest eruption which are piled up near the crater as bombs and large lumps of lava were determined by Brouwer as hypersthene-augite-andesites, augite-andesites and basalts; on the middle crater rim a few fragments of acid pumice were found. In the pyroxene-andesites, the augite content, with one exception, is much higher than the hypersthene content. Augite and hypersthene were sometimes intergrown. The olivine-content of the basalts was slight. Brouwer reports hornblende to be absent from both the rocks and their inclusions.

It may thus be assumed that the volcanic ash from Ternate will be characterised by the preponderance of augite as dark mineral, the presence of few hypersthene and still less olivine and the absence of hornblende.

Motir, as Verbeek (168) says, (p. 143) is a cone-shaped flattened mountain, composed chiefly of loose material. Wichmann (179) concludes from accounts by Forrest that there was a single insignificant eruption in 1774. Verbeek found a lava flow on the north west only, which consisted of basalt with inclusions of lumps of augite-hornblende-andesite. The basalt contained plagioclase and augite phenocrysts as well as numerous small olivines, while in the groundmass plagioclase, augite, iron ore and brown glass occur. The inclusions were almost all crystalline with plagioclase, dark brown hornblende and magnetite as phenocrysts in a small amount of groundmass, composed of felspar, augite and iron ore.

Wichmann (179) recounts various violent eruptions of the volcanic island of *Makian*; Kemmerling (86) mentions them also. They took place in July 1646, September 1760, 1861—1864, June 1890. In Dec. 1861 there was a violent outburst, which continued in a milder degree during 1862—1864. In 1890 the eastern crater was active.

Verbeek (p. 142) took samples in 1899 of the rocky delta, belonging to the eastern crater, which he says is strewn with thousands of loose andesite blocks and sand of fresh blue-grey colours, derived from the last eruption in 1890. He describes these as ordinary fresh pyroxene-andesite with grey felty microlites; the strongly pleochroitic hypersthene is surrounded by monoclinic augite.

A comparison of the rocks of the above named volcanoes with the composition of the volcanic ash in sediments 345, 344 and 347, yields a somewhat negative result. It might be assumed that the ash in sample 347A is principally derived from the peak of Ternate, or possibly from Makian. This station lies about 60 km from the Peak of Ternate, the glass content of the ash amounts to a good 40%. But no opinion can be formed of the origin of the ash until more samples of a similar composition have been found.

The volcanic ash in samples 345, 344, 347B and 347C, considering its mineralogical composition, cannot be derived either from the Doekono, nor from the Peak of Ternate, nor from Motir. The ash in samples 345 and 344, which occurs in very superficial layers, might come from the Gamkonora or the Makian, as recent eruptions of these volcanoes are known to have occurred. The distance of stations 345, 344 and 347 from Gamkonora is 50 km, 100 km and 90 km respectively and from the Makian 150 km, 165 km and 95 km. It is most probable that the ash of samples 345 and 344 is derived from the eruption of the Gamkonora in 1673, but the supposition needs the confirmation of material from the volcano. According to Kuenen (table 2) upon the 5 cm thick layer of ash in sediment 345 there is 5 cm sand which has not been further examined.

Along the coast of Halmaheira at St. 346 there are strong currents, for, as Kuenen says, only „fragments of coral and sand" were raised. In a preparation of this sand, the composition of which is given in Table 9, the heavy minerals occurred in the ratio: augite: hypersthene: green hornblende: red hornblende = 20: 20: 12: 1. There is no olivine. The ordinary green augite and the highly pleochroitic hypersthene are sometimes intergrown. The glass content is low. The mineralogical composition shows no connection with the volcanic ash of sediments 345 and 344. The orgin of the sand in 346 cannot be determined.

In sample 347, which is 176 cm long, layers 0—6 cm (B), 80—86 cm (C) and 170—176 cm (A) have been sampled, moreover Kuenen recounts that the sampler carried right through some hard layers of coarse volcanic ash, occurring at 47—54 cm and at 133—136 cm. The material of the hard layer 47—54 cm consists of coarse sand, mostly of 0.2—1 mm diameter. With few organisms and clay casts, the layer contains unaltered volcanic material composed of andesite particles, basic plagioclase, a good deal of volcanic glass, iron ore and heavy minerals in the ratio augite: hypersthene: olivine: green hornblende: red hornblende = 3: 5: 1: 2: 0.1. It is not evident from where this material has been derived, the eruption products of the volcanoes on and near Halmaheira are not sufficiently known. It must be assumed that the material is derived from one of the recent volcanoes and that it either fell into the sea during a violent eruption by aeolian transport or was carried there by mud flows (lahars).

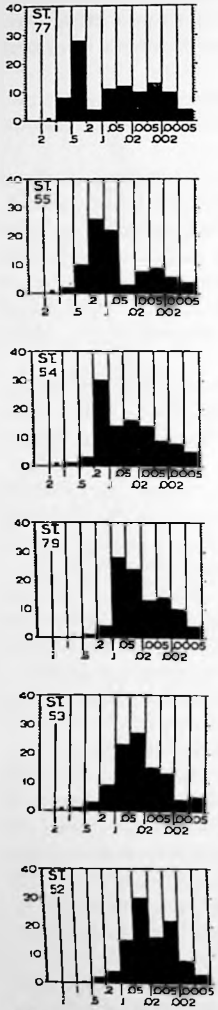


Fig. 10. Mechanical Analyses of Volcanic Muds of the Sangi Archipelago and the Celebes Sea.

It is worth noticing that this coarse-grained sandy volcanic material easily coheres in seawater, in contrast to volcanic ash. The same contrast between the behaviour of volcanic sand and volcanic ash may be observed upon land.

The origin of the ash in the three sampled layers is uncertain. In the deepest layer 347A it might come from Ternate and even partly from Makian. In layer 80—86 cm it might be derived from the Gamkonora or from Makian. In the upper layer 0—6 cm the ash cannot be identified at all. The glass content of this ash is some 25%. The most frequent heavy minerals are yellowish brown to blue-green, strongly pleochroitic hypersthene and moderately pleochroitic hornblende of yellowish green to green. The olivine is colourless. The hypersthene is sometimes found intergrown with brown hornblende, this brown hornblende is highly pleochroitic and has a small extinction angle. The content of this brown hornblende is very small. Up to now, an intergrowth of hypersthene with brown hornblende has not been reported from any active volcano in this part of the Archipelago, although Bey (7) has made note of it in andesites of the island of Morotai.

g^1. In the Globigerina Ooze 283 and 285 and in the Terrigenous + Volcanic Mud 284, north of Halmaheira, a little recent-volcanic material is found, which occurs in these samples besides the old-volcanic material. The recent-volcanic ash of the samples contains andesite particles, plagioclase, ordinary green augite, brown volcanic glass and less strongly pleochroitic hypersthene, green and red hornblende and iron ore. The augite and hypersthene are sometimes intergrown. The hornblende often occurs in laths with a glassy cover. The ash is probably derived from the Doekono and the Banoea Woehoe. The old volcanic material, which contains a.o. pale green augite and slightly pleochroitic hypersthene, plays a greater part in these samples, it will be discussed with the Terrigenous Muds.

h. Volcanic Muds of the Sangi Archipelago and the Celebes sea

Most of the Volcanic Muds of this area are distinguished from those near Halmaheira by a low content of volcanic glass. As may be seen from Table 10 and fig. 10 the glass content calculated in percentages of the ash, for samples 55, 54, 53, 52, 77, and 79 is 5, 11, 8, 13, 13 and 40.

The mechanical analyses in fig. 10, arranged according to grain-size, show that the low glass content of samples 55, 54 and 77 is accompanied by a high content of sand fractions. The mechanical analysis of 77 has peaks in the fractions 500-200 μ, 50-20 μ and 5-2 μ; it is a mixture of volcanic sand, volcanic ash and clay. The peaks in the mechanical analysis of 54 lie in the fractions 200-100 μ and 50-20 μ, that is at a somewhat finer volcanic sand and at volcanic ash. In sample 55 the peaks are in fractions 200-50 μ and 5-2 μ, that is with fine volcanic sand and clay. Here fraction 50-20 μ, which is characteristic as top

fraction of fine aeolian volcanic ash, is almost entirely absent. While the content of volcanic glass in samples 77 and 54 greatly increases in the fractions 100-20 μ, it is much less conspicuous in 55; the glass percentage in fractions 100-20 μ for 77, 54 and 55 is 33, 24 and 11 respectively. This makes it probable that aeolian transported material takes little or no part in the formation of sediment 55.

St. 55 is situated on the steep western submarine slope of the volcano Menado Toea, which as far as known has not been in eruption in recent times. The Menado Toea has not often been investigated. In Koperberg's (92) opinion (p. 62) the volcano is composed of pyroxene-andesite; in the samples he determined hypersthene predominates over augite. This corresponds to the mineralogical composition of sample 55, in which, moreover, olivine and hornblende occur, although in smaller quantities than in 77 and 54. Probably this admixture is derived from material from the surrounding volcanoes. The fact that the andesite particles in 55 are partly brown weathered in contrast to 77 and 54, supports the opinion that this sample is largely composed of material from the Menado Toea, weathered on land, which was transported to the the sea by rivers or land slides. It is also possible that eruptions of adjacent, still active volcanoes of the Minahassa contributed this material. The recent volcanoes of the Minahassa are the Batoe Angoes or G. Tongkoko, the Lokon, the Mahawoe and the Sopoetan, all of which are situated within 60 km of St. 55.

The *Batoe Angoes*, as reported by Koperberg (92, p. 59), consists of pyroxene-andesite to felspar-basalt, with few porphyritic pyroxene, in which hypersthene was uncertain. Eruptions took place in 1801 and 1821.

The recent products of the *Lokon*, according to Koperberg (p. 94—95) and earlier investigators are formed of olivine-containing pyroxene-andesites and basalts, in one single case rhombic pyroxene could be demonstrated, while augite is always found. No violent eruptions of this volcano are known.

The *Mahawoe* is said to have been in eruption about 1789 (quotation in Kemmerling (87) p. 107).

Stehn examined the rocks of one of the three small craters, found only in loose blocks, which he determined as augite-andesite.

The *Sopoetan* has had violent outbursts in 1785 or 1786, 1819 and 1833 (see Kemmerling p. 141—143) in which the ash was scattered as far as Menado. It is regarded as the most active of the Minahassa volcanoes. In the activity reported after 1833 (or 1838) no great distribution of volcanic ash took place. Concerning the eruption in 1833 it is reported that in Amoerang 4 inches of ash fell. Slides of debris take place in the bay of Amoerang during violent eathquakes, as reported by Kemmerling (p. 152). Deposits of Volcanic Mud, chiefly consisting of Sopoetan products are thus to be expected in the bay of Amoerang. On map I, therefore, the boundary of Volcanic Mud is drawn at this bay.

Recent Sopoetan material has been examined by Rinne (131), amongst others, who determined the sands, lapilli and rocks of the eruption of 1838 as olivine-containing augite-andesite; the shore sand at Belang proved to be of the same composition and he reckoned it amongst the Sopoetan products. Bücking (28) examined Sopoetan rocks, which as phenocrysts contain plagioclase, greenish brown olivine, dark green augite and magnetite; the groundmass consists of colourless or brown glass with augite, felspar and magnetite. Koperberg (p. 152) considers that the Sopoetan rocks stand between augite-andesite rich in olivine and basalt rich in plagioclase, while Kemmerling speaks of black slug-like basalt as a typical Sopoetan product. All the definitions, however, vary only to a small degree.

To summarize we may say that the products of the four active volcanoes of the Minahassa are augite-andesite, olivine-containing augite-andesite and basalt, in which there is little or no hypersthene.

The volcanic material of sample 55, considering its mineralogical composition, can therefore only be for a small part composed of products from the Minahassan volcanoes.

Of the minerals of the Volcanic Muds plagioclase, augite, hypersthene, olivine, hornblende and apatite contained in volcanic glass are found, while they are also to be seen in the rock particles as well as magnetite. The augite is pale green and green, sometimes slightly pleochroitic and sometimes not; the hypersthene is strongly pleochroitic from yellow to blue green; the olivine is colourless, yellow or pale green; the green hornblende is partly of elongated habitus, usually strongly pleochroitic from yellowish green to green or brownish green and from green to bluish green. The red hornblende is highly pleochroitic from yellow to red. Non-idiomorphic brown hornblende occurs in samples 77 and 79, sporadically in 55, 54 and 53 and is absent in 52. The above volcanic minerals are usually idiomorphic.

TABLE 10. Mineralogical Composition of Volcanic Muds in the Sangi Archipelago

No.	Fr.	rock particles and pumice	plagioclase I	plagioclase II	quartz	volcanic glass	augite	hypersthene	olivine	green and brown hornblende	red hornblende	biotite	miscovite	chlorite	apatite	epidote	magnetite and ilmenite
77	1	93	7														
	2	71	19				6	1	0,5	2							
	3	36	30			5	8	8	0,5	1		0,5					1
	4	35	28			14	3	8	0,5	2		0,5					2
	5	25	26			27	2	4	0,5	2	0,1	0,5			0,5		0,5
	6	8	37			28	1	2	0,2	1,5	0,2						0,5
55	1																
	2	6				3											
	3	35	2			1	0,1	0,2									
	4	44	15			5	3	4	0,5	0,1							
	5	37	21			8	2	4	1	2	0,5						1
	6																
54	1	10															
	2	15	2														
	3	50	10			4	2	1,2	0,3	1	0,1						3
	4	50	16			6	2	2	0,5	1	0,1						0,5
	5	25	25			15	1,5	4	1,8	1,2	0,1						0,5
	6	12	37			20	1,5	3	0,5	2	0,5						0,5
79	2																
	3	4	1	tr.		6		tr.									
	4	10	4	0,1	tr.	26	tr.	1		tr.		tr.					
	5	23	20	tr.		30	1	2	0,1	1,5	0,3	tr.				tr.	1
	6												tr.				
53	1																
	2																
	3	8	4			2	tr.										
	4	30	22			6	3,5	5,5	1	3							1
	5	30	35			7	3	8	1,5	3	1	tr.			tr.		5
	6																
52	2																
	3																
	4	7	5			7	0,1	0,1		0,1							
	5	28	29			9	3	5	tr.	10	0,5				0,1		0,5
	6																
290	1—5	6	16			5	2	1	0,1	0,5	0,1	0,1		0,3			0,3

In order to compare the mineralogical composition of the Volcanic Muds with that of the Sangi volcanoes the latter must first be discussed. The Sangi islands have been described by Brouwer (15), Wichmann (182) and Kemmerling (87), as well as others. Going from south to north the active volcanoes are the Roeang, the Api Siaoe, the Banoea Woehoe and the Gg. Awoe.

The *Roeang* is reported as active since 1808. The most violent eruptions took place in 1808, March 1871 and May 1914; fairly strong outbursts took place in April 1836, Aug. 1870 and April-May 1904. The last named eruption has been described by Koperberg (91); the after effects continued till 1905. Eruptions of ash and showers of stones as well as avalanches of stones, glowing clouds and incandescent flows of debris and also ejections of lava are recorded. In the eruption of 1914 (Brouwer p. 12) the entire island of Tagoelandang was covered with ash. On May 29th even stones of 30 cm diameter reached the island in the evening. On May 30th, clouds of ash are mentioned, driven by the strong east wind. The time of the eruptions lead us to expect in general a wide distribution of ash in a westerly direction.

The habitus of this volcano, which has a broad top in comparison to its base is explained by Kemmerling by the slopes of the volcano being so steep that sand, lapilli and bombs cannot remain lying where they fall. The consequent „avalanches sèches" cause a strong erosion of the top part of the mountain and only the solid lava masses remain standing.

It may thus be assumed that a great deal of recent material from the Roeang has fallen into the sea, that this material is both aeolian ash and ash carried into the sea from the slopes.

The rocks of the Roeang, according to Koperberg's report, both the younger and older products,

pyrite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Pteropods	Ostracode valves	calcareous Sponges	calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
			100														0,14
			99,5	0,5							0,5						7,5
			90	4							4	5	1		6		27,9
			93	3	1						4	1	2		3		3,7
			88	5	1						6	5	0,9	0,1	6		11,3
			78,4	—3,6—						5	8,6	11	1,9	0,1	13		12,5
										†						†	0,1
		3	12	72	8	tr.					80	5			5	3	2,0
		2	40,3	51	6					0,7	57,7	2			2		10,1
		1	72,6	18	2					5,4	25,4	1	1		2		26,5
		1	77,5	15	1,5	tr.			0,5	4,5	21,5	1	tr.		1		22,2
		4	65						0,5		28	6	0,5	0,5	7		3,0
		90	100														0,3
		80	97	2							2	1			1		1,4
		17	88,6	7	0,4					1,5	8,9	2			2	0,5	2,7
		14	92	2,7	0,3					3	6	1,5	0,5		2		29,8
		17	91,1	2						1	3	5	0,5		5,5	0,4	13,7
		9	86	1,5						2	3,5	8	2		10	0,5	16,4
		5	5	90							90	3			3	2	0,3
		18	29	56	2						58	10	3	tr.	13	tr.	1,3
		7	48	33	0,5					0,5	34	5	13	tr.	18	tr.	4,0
tr.		3	82	16					tr.	tr.	16	1,8	0,2		2		27,6
0,2		3	63						0,1		30	3,5	3	0,5	7	tr.	24,4
		†															0,06
		100	100														0,9
		85	99	1							1						2,6
		27	99	1							1	tr.	tr.		tr.		9,2
		5	98,5	0,2							0,2	1	0,3		1,3		23,4
		5	95									4	0,5		4,5	0,5	27,5
		100	100														0,3
		100	100														1,5
		80	99,3										0,7		0,7		4,5
		15	100										tr.		tr.		15,1
		20	97									1,7	1	0,3	3		29,6
	0,5		32	40	3	0,3	1	0,2	0,5	13	58	9,5	0,5		10		69,1

consist of hypersthene-augite-andesite, with quantities of idiomorphic plagioclase, hypersthene, augite and magnetite. The plagioclase predominates, while the hypersthene is somewhat more abundant than the augite. Hornblende occurs as accessory compound. Koperberg describes homogeneous inclusions, in which are found combinations of plagioclase, hornblende, augite, olivine and hypersthene.

Brouwer, who examined a large number of rocks, found both hypersthene-augite-andesites and hypersthene-augite-amphibole-andesites, with fairly strongly resorbed brown amphibole amongst the oldest volcanic products, especially the lava on the north west of the old crater wall. These rocks were also found along the shore and on the slopes of the volcano. He found one augite-hypersthene-amphibole-olivine-basalt with rounded olivine. He describes numerous inclusions of volcanic products; a great number of the inclusions contained amphibole, which might be either resorbed or non-resorbed brown amphibole, or pale green, green and greenish brown amphibole. Plagioclase is always present in these inclusions, hypersthene, augite and magnetite frequently occur, while olivine is a much less usual component of the inclusions. The olivine is seldom idiomorphic.

Gisolf (87) has described also inclusions from the Roeang.

The *Goenoeng Api Siaoe* has been called by Kemmerling the safety valve of the Sangi Archipelago, because it is always smoking. In recent times only mild eruptions are recorded from this volcano, so that the ashes cannot be distributed a great distance. The amount of material thrown out by the Gg. Api Siaoe is small in comparison with the activity of the other volcanoes of the Sangi Archipelago.

Bücking (30) has determined rocks from the Api Siaoe: they are augite-andesites with pheno-

crysts of plagioclase, pyroxene (a great deal of augite with a remarkable pleochroism from brown to greenish and less, strongly pleochroitic, rhombic pyroxene) and sometimes small olivines. The dense microlitic glass basis contains plagioclase, augite and iron ore. Kemmerling found similar products, he considers the older rocks also to be augite-andesites.

The *Banoea Woehoe* is a submarine volcano, lying 600 m west of Mahengetang. The history of its eruptions, so far as it can be known for this remote volcano, has been collected by Wichmann (182), Kemmerling (87) and Neumann van Padang (123, p. 80—82).

The oldest known outburst took place in 1835. Lava flows proceeded from it and in four days (April 23—26) an island 90 m high arose. In 1848 only a few small rocks were left of this, rising up out of the water. In September 1889 a fresh eruption must have taken place, causing a tidal wave 1.5 m high at Taroena and Sangi, while many dead fishes were washed up. According to accounts given by the missionary Steller to Wichmann in July 1894 the island consisted of a narrow strip of land, upon which stood a hill some 30 m high, consisting of volcanic sand and pumice. At the end of 1895 and in April and August of 1904, feeble submarine activity was reported during which on Aug. 27th 1904 the ejection of rocks and ash was observed. It may be concluded that there has been repeated slight submarine activity. Brouwer (15, p. 46) reports that in 1913 three rocks still protruded from the water, while on the sight of the crater 7—9 m of water stood.

From July 18th 1918 to the end of April 1919 the Banoea Woehoe was repeatedly in action; pumice, sulphur smell and strong smelling yellow mud were observed at sea. In Febr. 2nd two rocks were raised up out of the sea, on Febr. 3rd many rocks disappeared. On Mahengetang a great deal of ash fell. On April 2nd ash, stones and bombs as big as a human head reached Mahengetang, where they caused great damage. On April 26th the sea water was thrown up 1—5 m and at 500 m from the crater the temperature was raised 10° C.

In November 1919 the island was about 70 m large and in some places 12 m high, according to Brouwer's report, while the depth of the sea in the immediate neighbourhood was 3-45 m. While Kemmerling (87) met with a stoney shelf of about the same dimensions in May 1921, Stehn (123) in Aug. 1922 found that this rock had been converted into loose material so that he did not expect the island to last much longer. In 1935 it had disappeared, but when this occurred is not known.

In 1922 to the north of the island at 50 m distance a depth was sounded of fully 100 m; the water there formed a whirlpool with very strong suction. At 150 m west and 100 m south of the island there was a shallow bank, covered with small stones, outside which the depth of the sea rapidly increased.

The observations of the Banoea Woehoe are here given in some detail to make clear that not only is there frequent activity, but also that the distribution of material of this submarine volcano is much more intensive than with most land volcanoes in the Eastern Indian Archipelago.

Rocks from the Banoea Woehoe were collected by Steller in 1894 and examined by Wichmann (178), who considers that only the hornblende-andesite-pumice, which with sand is the principle component, are derived from the eruption of 1835; while the rest of the augite- and hornblende-andesites have undergone such a considerable alteration that possibly they should not even be regarded as older eruption products of the Banoea Woehoe but as having come from elsewhere. Kemmerling considers that the augite-andesites are derived from the old volcanic island of Mahengetang. The volcanic sand, collected on the shore of Banoea Woehoe in 1894, was composed of much plagioclase, pale green augite and ilmenite, with a little brown hornblende and very little hypersthene. The hornblende-andesite-pumice from 1835 consists of a groundmass of colourless, filiform glass with gas inclusions, containing only plagioclase and green hornblende as phenocrysts with a very little iron ore and an occasional augite. The hornblende is mostly crystallographycally well defined and shows no resorbtion, in contrast to the green hornblende in the older rocks. The pleochroism is: c. dark green, b. brownish green, a. grass green. The extinction angle is 14—18°. As inclusions a little iron ore, some apatite and glass are found. In the plagioclase there are inclusions of glass, gas and a little hornblende and augite.

Both Brouwer and Kemmerling defined the rocks of the eruption of 1918—1919 as hornblende-andesites, rich in glass, with plagioclase, little iron ore and with green, unresorbed amphibole, which Brouwer reports to be often idiomorphic and strongly pleochroitic from dark brownish green to pale yellow.

The eruptions of the *Goenoeng Awoe*, which forms the northern part of the island of Sangi, have repeatedly caused catastrophies. Wichmann (182) and Kemmerling (87) have summed up its activities. The oldest known eruption began with a shower of ash in Dec. 1640, when a light ash rain fell even upon the peninsula of Zamboanga (S.W. extremity of Mindanao). On Jan. 3rd and 4th 1641 a report like canon was heard. On Jan. 4th there was complete darkness from 2 o'clock p. m. to 2 o'clock at night, which spread over almost the whole of Mindanao. The shower of ash which caused the obscurity, fell even upon the islands of Cebu and Panay (Philippines), but was particular dense upon the island of Jolo, lying 520 km west-north-west of Sangi.

In Dec. 1711, Aug. 1812, March 1856 and June 1892 ash eruptions took place, all accompanied by streams of hot lahar. The mud flows were caused by the ejection of the crater lake and descended through the ravines partially into the sea, causing great damage, as did also the glowing clouds and hot ash clouds. Ash from the eruption of 1856 spread as far as Mindanao, while it was afterwards carried in another direction by a northerly wind. It is known of the eruption in 1892 that the ash reached the islands of Talise and Bangka in a southerly direction; on the island of Great-Sangi 6—15 cm ash fell. For months after the outburst hot mud flows (lahars) came down the ravines.

Material from the Gg. Awoe was thus widely distributed by the ash eruptions, while a great deal of material reached the sea in lahars.

Kemmerling considers that in the rocks of the Gg. Awoe two stages may be petrographically distinguished, that of the pyroxene-andesites and that of the hornblende-pyroxene-andesites. The pumice-like slugs of the 1892 eruption are pyroxene-andesites rich in glass. The rocks which build up the top are principally hornblende-pyroxene-andesites of varying composition, besides pyroxene-andesites. Usually they contain more augite than hypersthene, but sometimes the quantities are about the same; very occasionally an olivine is met with. The material of a mud flow of 1892 consists of much glass, of dust of alteration products carried with it and of plagioclase with much less yellowish green augite and iron ore according to Wichmann. He also reports much plagioclase, less augite and little hypersthene in glass in the pumice of this eruption. Wichmann found in the material from the Gg. Awoe collected during the Siboga-expedition hornblende-augite-andesites etc. Bücking (30) describes augite-andesites, sometimes containing olivine from the neighbourhood of Taroena.

The volcanic material from the Globigerina Ooze 290 corresponds to the eruption material of the Gg. Awoe (see Table 10) as defined above.

The mineralogical composition of the Volcanic Muds 77 and 54, in Table 10, proves to mutually correspond in so far that in the coarse sand fractions augite is relatively better represented than hypersthene, while in the fine sand fractions hypersthene is the predominent heavy mineral. With the exception of 290, in the samples of Table 10 hypersthene altogether predominates to a greater or less degree. Of all the active volcanoes of the Minahassa and the Sangi Archipelago the hypersthene content of the eruption products of the Roeang is the only one parallel to this. The habitus of olivine and the occurrence of a moderate amount of brown as well as greenish brown and green amphibole indicate, with other peculiarities, that the volcanic material of sediment 77 is derived principally from the volcanic island of Roeang, lying at 45 km distance. The coarse-grained sand in the sample was probable carried westwards by marine currents. Most of the currents in the Celebes sea run in this direction at 100—400 m depth, according to Lek (100), while superficial water from the Celebes sea flowes into both the Soeloe sea and Strait Makassar. The force of the resultant currents at St. 308 varies according to Lek from 36 to 80 cm/sec. A current of this strength would be sufficient to account for sand of 0.2 mm. diameter that had entered the sea with lahars being transported to St. 77. The rate of settling of particles of 200 μ diameter in still water is 80—85 m per hour. The transport in a water column of 2800 m (= depth St. 77) with a velocity of the water of 36—80 cm/sec is then $35 \times 3{,}6 \times (0.36—0.80)$ km = 45—101 km. There are no observations upon the velocity of currents in the Celebes sea. It is difficult to estimate the effect of the strong east winds upon the aeolian transport of sandy material from the Roeang; a more obvious factor would be the sliding of material. The fine sand and silt fractions of this sample which contain more volcanic glass must be material from the Roeang transported by air.

Sediment 79, which consists principally of volcanic ash with a peak in the diameters 100—20 μ (fig. 10) is of analogous mineralogical composition to the fine sand and silt fractions of sample 77,

except that the glass content is relatively higher and the content of rock particles and heavy minerals is lower. This sediment lying 60 km south east of the Roeang, is principally composed of aeolian volcanic ash from the Roeang; besides it contains fine terrigenous material, of which the sporadic biotite, non-idiomorphic, yellowish brown to red-brown and green-brown, the muscovite and the epidote form a part.

Sample 54 differs from sample 77 in having fine idiomorphic olivine and by the brown hornblende being only sporadic. This sediment, only 10 cm thick, must be of recent origin. The relatively higher augite content of 54 in fractions 500-100 μ, together with the presence of fine idiomorphic olivine, indicates the possibility of the sediment containing material from the Lokon or the Sopoetan as well as from the Roeang. The first two volcanoes lie some 45 and 80 km from St. 54, while the distance from Roeang is about 105 km. The part played by slumped material from the bay of Amoerang cannot be immediately estimated.

Samples 53 and 52 differ little in grain-size; both the mechanical analyses show peaks in fractions 50-20 μ, sample 52 has somewhat more clay fractions than 53, but it comes from deeper in the sediment (18—48 cm) than 53 (0—22 cm).

As in sample 55, the content of volcanic glass in samples 53 and 52 is remarkably low, although these samples have their peaks in the fraction 50-20 μ, in contrast to sample 55. This is accompanied by a relatively high content of heavy minerals of both 53 and 52 (Table 10). Although the mechanical analysis (fig. 10) suggests an aeolian ash in these samples, the possibility is eliminated by the low content of volcanic glass and the high content of heavy minerals. The recent-volcanic habitus of the minerals stamp the material, nevertheless, as young-volcanic, raising the question of how this material could be deposited at such a great distance from the active volcanoes.

Mineralogically the material of sample 52 largely corresponds to that of the recent Banoea Woehoe products described above and to a less degree with that of the Roeang, if the older products of this volcano are ignored. The same origin holds for 53, although here the Roeang material predominates, while a certain amount of admixture from the Sopoetan is not impossible, considering the relatively high olivine content of the sample.

The distance of St. 53 from the Roeang and the Banoea Woehoe is 145 km and 190 km respectively, while from St. 52 they are 330 and 320 km. The distribution of Banoea Woehoe material must be almost entirely due to water transport, as shown by the history of the eruptions of this submarine volcano. Products of the Roeang could be conveyed both by water and by aeolian transport. Corresponding to the greater distance of St. 52 from the volcanoes, the heavy minerals in sample 53 have a diameter up to 200 μ, while those in sample 52 are seldom greater than 100 μ.

If the rate of settling of particles in still fresh water is applied a mean current velocity of 37 cm/sec. must be assumed for the transport of particles of 100 μ over a distance of 330 km at 5000 m depth, for the transport of particles of 200 μ over 145 km at a depth of 5000 m a mean rate of current of 64 cm/sec would be required. The factors mentioned below, which are here not taken into consideration, make the values in this calculation too high.

1. The settling takes place in salt water, which has a greater boyancy than fresh water, so that the sedimentation will be slower.

2. The settling velocity decreases with the temperature; the values calculated apply to approximately 27° C, while according to the observations of the Snellius-expedition the temperature at the bottom of the Celebes sea falls to 3.3° C., hereby the settling velocity decreases about 40%.

3. As Hjulström (77, 78) has explained, laminar movement, that is the water particles moving along parallel courses, usually only occurs at a low velocity of current, as a rule there is a turbulent flow of water particles. Each current has a certain critical velocity that may not be exceeded if the laminar motion is to be maintained. In ordinary streams this critical velocity is very low, a fraction of a millimeter per second; the greater the depth, the smaller the critical velocity. Turbulent flow is characterized by a variety of mixed movements, which produce a disturbed eddying motion. The nature of turbulence is not yet well known. It is assumed that in a stream, characterized by water moving in turbulent flow, particles of water are continually moving upward and downward. On the average these upward and downward motions counterbalance one another. Therefore over an extended period of time the vertical motion in a horizontally flowing stream must be zero. It is possible, how-

ever, that the water moving upward may have a greater silt content than that moving downward, with the result that sediment is transported upward in the stream.

Each particle that is forced upward has its own particular settling velocity; thus the position of the particles in the water is determined by the result of these two opposing factors, the turbulent motion which causes the particles to rise and the force of gravity which makes them sink.

This is an important factor which may delay or even prevent the deposition of particles of a particular size and specific gravity. The same factor has been observed to cause material in the sea sometimes to be sifted according to the diameter of the grains.

4. The particles may be not only transported by marine currents while settling, but after settlement they may be effected by bottom currents. Van Veen (164, p. 48) deduced from the research on the currents in the Vlie that a current at 15 cm above the bottom of about 1 m/sec could stir sand of 500 μ diameter, while a current of 50 cm/sec at the same distance from the bottom would move sand of 250—200 μ. These values change with the local conditions, such as undulation of the floor, to which turbulent bottom currents will give rise and the greater or less compactness of the sand.

Van Veen also relates laboratory experiments by J. Th. Thysse, where one result obtained was that sand of approximately 500 μ begins to roll with a current of 30—50 cm/sec measured at 15 cm from the bottom.

According to Hjulström the velocity of the rolling grains is less than that of the bottom current and is lower the smaller the size of the sand particles.

It seems improbable that there are currents in the flat middle part of the Celebes sea which would be strong enough to transport fine sand. However, in and near the straits of the Sangi Archipelago strong bottom currents may be expected. According to Van Riel (130) it is highly probable that the deepest entrance to the Celebes sea occurs in the Kawio strait; in that case the saddle depth must be about 1400 m, according to the course of the isotherms. Van Riel records a sill current in the strait of Siaoe as well as in the strait of Kawio, through both of which water from the Sangi trough enters the Celebes sea. Here there are rapid currents which can be followed for some distance along the slopes to the bottom of the Celebes sea, as is confirmed by the composition of samples 289 and 298, which consist entirely of stones and coral (Table 2) and by the fact that at St. 297 hard bottom was found at 2600 m depth in the Celebes sea, showing that here west of the Kawio straits there are very strong bottom currents. The observations by Stehn (123) in 1922 of a whirlpool with very strong suction 50 m north of Banoea Woehoe also indicates the possibility of the distribution of volcanic material by bottom currents. It is not known at what distance from the sills these bottom currents have a still significant velocity. We are aware that in this way a sufficient ventilation of the water of the Celebes sea is brought about, which is manifested in the comparatively low lime content of both the Volcanic and Terrigenous Muds of the Celebes sea.

Considering the strong currents in and near the straits of the Sangi Archipelago it seems probable that the distribution of the material from the volcanoes of this Archipelago to a greater distance is chiefly carried out by these currents and that aeolian transport will be responsible to a lesser degree.

h^1. Terrigenous + Volcanic Muds in the Celebes sea and the Molukken sea

The mineralogical composition of these sediments is given in Table 11. In samples 343, 338, 337, 336, 335 and 333 a certain amount of recent-volcanic material was shown, characterised by light brown to brown, porous volcanic glass, with green faintly pleochroitic augite and strongly pleochroïtic hypersthene; the material resembles the volcanic ash found at St. 79, which is derived from the Roeang. The content of recent volcanic ash in the samples from the Molukken sea is lowest in 333 and 337.

Besides this recent material the sand fractions of these samples contain minerals of terrigenous, chiefly old-volcanic origin.

In 337 and 338 the fibrous green hornblende has partly been altered into chlorite. This habitus is accompanied in sample 337 by altered volcanic material, including green schists, and by soft sandstone from volcanic material, with andesite particles; in fraction 50-20 μ there is a good deal of chlorite and chloritic alteration products.

In samples 343, 333 and 335 detritus of old-volcanic material is also present, containing colourless or pale green augite, slightly pleochroitic hypersthene or bronzite and pale green or green

TABLE 11. Mineralogical Composition of Terrigenous + Volcanic Muds

No.	Fr.	rock particles and pumice	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green and brown hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	piedmontite	staurolite	zircon	tourmaline	garnet
343	1 2 3 4 5 6	1 3 16	1 3 11	0,3		tr.	3 16 37 45	0,2 0,3 2,5	0,2 0,6 2,5			tr. 1,5	tr. 0,3	0,5		0,1		tr. 1	tr.	0,8					
338	5	24	15				15	1	2		tr.	1	tr.	tr.				0,1	tr.	tr.					
337	Gr. 1 2 3 4 5 6	† 95 60 54 50 44	1 8 18 18 23	1 12 1 2 2		3 2 tr. 0,5 1	0,5 2 5	2 2 1,5 1	1 2 1,5 2			1 0,5 4 5	tr. 0,5 1					†		tr. 1			tr.		
336	2 3 4 5 6	15 20	6 20				3 15 26	0,2 2	0,3 4		tr.	tr. tr. 1	tr.	tr.		0,1 tr.			tr.	tr.					
335	5	7	8	0,5			29	0,5	1,5			0,5		0,7		0,5		0,5	tr.	0,2				tr.	
333	2 3 4 5 6	6	1 8	8	0,2	3	1 3 20	1	0,1 2			1	0,2	3		1 1	0,1 2	2	tr.	1,5		0,2	0,1	0,1	0,3
301A	2 3 4 5 6	† 18 30 30	30 24 29	0,5	0,3		22 14 14	0,5 2	0,3 2			12 14 8	3	0,3	tr.	0,1 0,5	tr.	0,2	0,5	0,1					
301B	2 3 4 5 6	1 3,5 20	6 20		tr.		tr. 6 10	3	2	2	0,2	1 4 13	3	1		1		tr.	0,5	1					tr.
56	1 2 3 4 5 6	1,5 10 20	5 20 25				7 18 20	0,5 1	0,5 1,5		tr. 0,2	2 12 14	0,1 2	0,3	tr.	tr. tr.	0,5 tr.	tr.	0,3 1	tr.					
58	1 2 3 4 5 6	1 0,1 8 12	1 0,5 5 10	1 3		0,5	0,2 5 6	1 0,1 0,2 0,2	0,1			2 6	1	tr.		0,1 0,1 0,1	1 1 0,3	0,1 0,1	tr. tr.	1					
303	3 4 5 6	2 4 7	1 8 16	tr.		tr.	8 7 14	1	1,5	0,2		0,3 4 14	2	0,1		0,2 0,3 0,5		0,1	0,5	tr.					
75	3 4 5 6	2 5	0,5 6	2 28		0,5 18	0,5 3 6	0,1 0,5	1			tr. 3	tr.	0,5		0,5 0,1	6 0,1 0,5	0,1	tr.	0,2			tr.	tr.	
76	2 3 4 5 6	tr. 22	0,5 13	tr. 0,2 13		tr. 0,2 7	3	1	2			2	0,3	0,3		tr.	2	0,5		0,2			0,1	tr.	
48	3 4 5 6	0,5 5	0,1 7	tr. 0,1 7	0,1	4	4	0,2	0,2			2	tr.	0,5		0,5	2 0,5	0,3		0,3					tr.
41	3 4 5 6	0,5 0,5 7	tr. 17	tr. 20	3	10	1			0,5		9		4		11 27 12	13 3,5 1	0,1	3	0,2			0,5	tr.	0,2
40	3 4 5 6	1 8	1 2	1 0,5 35	0,5 3	16	0,1	0,8	0,6	tr.		tr. 2,6	0,1	3	0,1	1 3 6	3 1 2	1	0,3	1,5	0,1		0,5	tr.	0,3
39	1 2 3 4 5 6	16	3	28	3	14	0,1	tr.	tr.	tr.		7		2	tr.	7 7	1 1	1	0,2	1			tr.	0,1	tr.

in the Molukken Sea, the Celebes Sea and Makassar Strait

titanite	rutile	chromite	magnetite and ilmenite	manganese oxides	pyrite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Pteropods	Ostracode valves	Alcyonarian spicules	calcareous Sponges	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
tr.		0,1	0,1 0,3 tr.	0,2 0,5 0,2 0,5 0,1		1,8 1,5 0,8 1,5 0,4	98 98 91 74 25 15	100 100 97,5 99,3 99 99,5	0,5 0,1 tr.									0,5 0,1 tr.	2 0,6 1 0,5			2 0,6 1 0,5		0,5 2,1 3,8 2,2 10,7 24,3
			1				1	60,1	--36,3--						0,1			36,4	3	0,5	tr.	3,5		29,0
			1 1 3				12 15 14 7 2	100 98 94 95 95 91	2 6 3 4								†	2 6 3 4 5	tr. tr. 1 2	2 2		tr. 2 1 4		14,5 2,6 5,7 9,2 9,2 12,8 10,3
			2				7 15 5 5	10 51,6 80 67	99 84 35 17	1 1 1 1	tr.							100 85 36 18 22	0,5 tr. 1 5	4,5 12 1 5	1	5 12 2 11	tr. 0,4 tr. tr.	0,4 1,0 3,0 9,8 18,0
			2				5	56	42	tr.								42	1	1		2	tr.	7,1
			2		0,3 2 1	0,5	1 5 4 5	2 10,5 68,2 66	100 93 60 --29,5--	2 2,5								100 95 62,5 29,5 24	1 1 1 7	1 25 1 2	tr. 0,5	2 26 2 9,5	1 1 0,3 0,5	0,2 0,3 1,2 5,0 16,6
			1 3				† 17,5 14,6 3 2	99,5 98,5 96,4 96	0,5 1									0,5 1 tr.	tr. 2 3	† 0,5 1 0,5 1		0,5 1 2,5 4	tr.	0,04 1,0 1,7 12,2 23,9
		tr.	2			0,2	100 98 80 20 10	100 100 99,5 99 98,5	0,2 tr.									0,2 tr. 0,5	0,3 1 1	tr.		0,3 1 1		1,4 4,5 5,1 9,2 27,7
			0,1 3				† 100 84 36 10 6	100 100 97,5 98 91	0,5									0,5	tr. 1 1,9 8	1 0,1 1		tr. 2 2 9	tr.	0,02 0,15 1,3 2,1 8,7 20,0
tr.			1		tr. 1 1		† 10 15 11 2 1	13 17 33,5 44,3 35	† 70 67 42 18	† 6 2 3 2	2 0,4 0,5 0,5	0,2 1	† 0,3		0,1 6 3		† 8 2 7 22	86 72 53,5 48,5 48	10 8 7 15	4 tr. 1	tr.	10 12 7 16	1 1 1 0,2 1	0,03 0,2 0,9 3,7 15,0 19,4
			1				86 75 35 20	97,5 98,3 93 81	2 1 3		tr.							2 1 3 9	0,5 0,5 4 10	0,2 tr.		0,5 0,7 4 10	tr.	0,9 3,2 8,6 17,1
			1			tr.	87 86 24 9	94 94,3 94 93,5	1 2,7 2								2 tr. 1	3 2,7 3 1	3 1 3 5	2 tr. 0,5		3 3 3 5,5		1,1 2,3 8,2 14,7
tr.			1		tr. 1	tr. tr.	† 100 96 33 15	100 97 98,5 89	0,3 0,2					0,2			0,5 0,3	1 0,5 0,5	tr. tr. 1 7	2 tr. 2	0,5	tr. 2 1 9,5	1	0,1 0,3 1,5 3,4 16,4
			0,5		1 3		100 85 11 8	100 87,7 44,1 53	tr. 3 24	3	tr.	tr. 0,5		0,3	4 4	0,1	1 15	tr. 4 46,9 32,5	4 8 11	4 1 2	tr. 0,5	8 9 13,5	0,3 tr. 1	0,2 0,8 5,0 17,9
tr.			3		tr. 1		65 55 5 3	89,5 86 96,5 94	8 6,5 2	0,5 0,5					tr.			8,5 7 2 4	tr. tr. 1 1	1 5 0,3 0,5		1 5 1,3 1,5	1 2 0,2 0,5	0,4 0,7 15,1 21,7
0,3	tr.	tr.	1		tr. tr.		91 85 12 5	96 92 96,5 98	2 ---5--- ---1---		1 2 0,5							3 7 1,5 0,5	0,5 0,5	0,5 1 0,5 0,3	0,2	0,5 1 1 1	0,5 1 0,5	0,7 0,6 5,4 23,7
tr.	tr.		1		0,3		† † 70 80 12 6	70 88 96,5 96,8	1 2									1 2 1	1 1	0,2	tr.	1 1,2	† † 30 11 0,5 1	0,35 0,25 2,6 1,2 19,0 27,0

hornblende, with sometimes fibrous green hornblende. The minerals often display ragged ends in contrast to the brown, little altered hornblende which occurs in sediment 343 (as in sample 79).

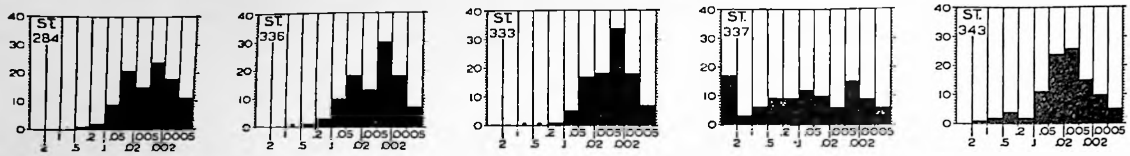


Fig. 11. Mechanical Analyses of Terrigenous + Volcanic Muds north of Halmaheira and in the Molukken Sea.

In sample 336 minerals of terrigenous origin only occur sporadically, nevertheless the mechanical analysis in fig. 11 shows that fine terrigenous material plays a great part in sample 336 as well as in sediment 333 and in the Globigerina Ooze 335 (fig. 25)). The peak in fraction 50-20 μ of 336 is caused by the volcanic ash, according to the mineralogical composition. In sediment 343 the high fraction 50-20 μ is principally due to the large ash content of this fraction. The mechanical composition of 337, on the other hand, is practically entirely determined by the size of the terrigenous material.

The terrigenous components of sediment 333 differ a good deal from the samples in the Molukken sea included in table 11, they will be discussed with the Terrigenous Muds.

Sediments 301, 56, 58, 303, 75, 76, and 48 from the Celebes sea contain the strongly pleochroitic, green hornblende, often occurring in long prisms, of which the habitus corresponds to the green hornblende in the Volcanic Muds 52 and 53. The content of this mineral is remarkably high in samples 301, 56 and 303 as well as in 52. The content of volcanic glass is somewhat low in comparison to the hornblende-content.

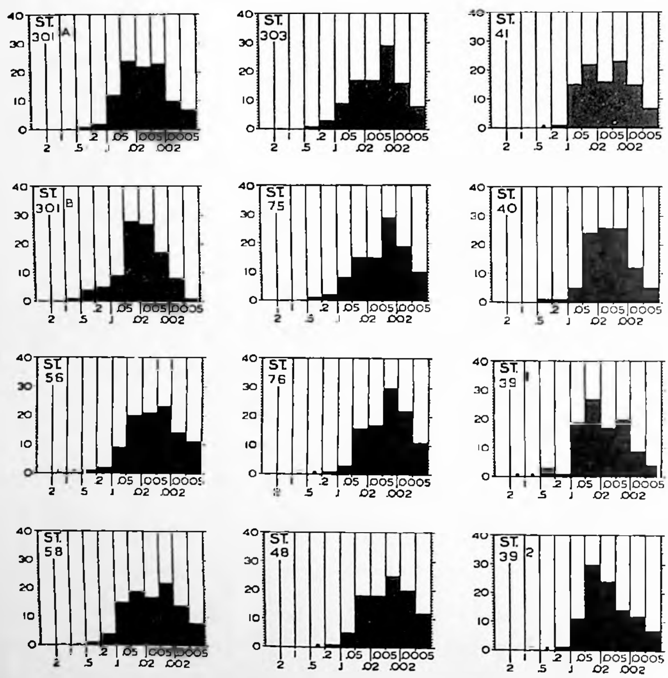


Fig. 12. Mechanical Analyses of Terrigenous + Volcanic Muds in the Celebes Sea and Makassar Strait.

The mechanical analyses in fig. 12 represent the admixture of volcanic material as a curve of which the peak lies in fraction 50-20 μ; showing that 301 has the highest content of volcanic ash of

these mixed muds, in 56 and 58 the content is lower, while it is lowest in 303, 75, 76 and 48.

The widespread distribution of volcanic material in the sediments of this region, as in the Volcanic Muds, can only be accounted for by assuming a transportation by marine currents. Only subordinate importance can be ascribed to aeolian transport, owing to the comparatively high content of heavy minerals in the samples.

Detritus of hornblende-andesite forms the chief constituent of the volcanic material of these samples, which is probably derived from the Banoea Woehoe. If the hornblende content be taken as measure of the transportation of the Banoea Woehoe material, it seems to be most marked in a north-westerly and westerly direction, while in a south-westerly direction the transport gradually diminishes.

Another possibility is that the so-called „submarine volcano 1922" (123), for the existance of which only one report vouches, yielded a similar material and that it was transported along the sea-floor. This volcano is said to have been observed at 3°58'N and 124°12'E. But even if it exists it does not explain how the products could reach St. 53 and others lying far to the south of it. It is, however, not impossible that both the Banoea Woehoe and „the submarine volcano 1922" contributed to the volcanic material in the Celebes sea.

Besides green and red hornblende, often idiomorphic, in samples 301A, 56, 303, 76 and 75, as well as sporadically in 48 and 58, fresh, green and pale green augite is found and highly pleochroitic hypersthene; both of these occur also idiomorphically in glass. This may be connected with a certain amount of admixture of Roeang material, especially in samples 75 and 76; in samples 301A, 56 and 303 there may be a contribution of volcanic ash from the Gg. Awoe on Sangi, of which it is known that in 1641 and 1856 the showers of ash were widely distributed in a north-westerly direction, as the pale green and green augite, occurring in these samples corresponds to that in sediment 290, where augite predominates as dark mineral.

The pyroxenes at St. 301 in the upper layer of 0—10 cm (301A) and of the lower layer of 66—67 cm (301B) display widely differing habitus. The monoclinic pyroxene of 301B is usually colourless or very pale green and not idiomorphic, the rhombic pyroxene is colourless or faintly pleochroitic from pale green to green, sometimes showing striae parallel to the c-axis and then seems to be composed of parallel lamellae. Moreover there is an intergrowth of lamellae of monoclinic pyroxene with enstatite. This enstatite-augite is also observed in samples 303 and 41. The pyroxenes of the bottom layer 301B, therefore, with the exception of the sporadic fresh, green augite, are not derived from recent-volcanic material.

All the sediments from the Celebes sea included in Table 11 contain moreover terrigenous components of non-volcanic origin. In samples 75, 76 and 48 there are small quantities of non-idiomorphic, almost colourless augite and slightly pleochroitic rhombic pyroxene. These components will be discussed with the Terrigenous Muds.

Small quantities of detritus of hornblende-andesite are found in the Globigerina Oozes 64, 65 and 66, in the Coral Mud 59 and in sample 63. The origin of this material cannot be given, especially because very little is known of the active volcanoes of Mindanao. According to Musper and Neumann van Padang (117) there are two volcanoes, the Ragang and the Calayo, situated at 7°40'30"N and 124°34'E and at 7°48'20" N and 125°4' E respectively. According to later reports from Musper (118) all that is known with certainty of the Calayo is solfatara activity.

Masò (106) reports outbursts from the Ragang in 1840 and 1873; from 1873 at least one violent eruption is known which scattered ashes in a north-westerly direction; concerning the eruption of 1840 he quotes the following „Of the eruption of 1840 Perrey says that about the 5th of April the boat Niantic, sailing in the Sulu Sea sixty miles west of Mindanao, received showers of ashes three or four times; while a British steamer, navigating about three hundred miles northwest of the Niantic received also, on the same date April 5th, similar showers of ashes. The prevailing winds in these seas in April are the east and southeast". Little is known of the eruptions of the Ragang in 1834, 1858 and 1871, according to Masò they are doubtful.

In the Soeloe Archipelago only extinct volcanoes are reported, namely by Smith (153) on the islands of Basilan, Jolo and Siasi. Musper and Neumann van Padang report that according to the researches of Guillemard and Smith the group of extinct volcanoes on Jolo consists of young effusive rocks of basaltic composition.

As far as the present writer knows, no rocks from these volcanoes have been determined, so that the origin of the volcanic material of the sediments adjacent to the Soeloe Archipelago cannot be traced.

i[1]. *Terrigenous + Volcanic Muds, containing ash from Oena-Oena*

Samples 41, 40 and 39, especially the first, are characterised by a remarkable content of fresh biotite (see Table 11) which occurs partly as idiomorphic green and red-brown hexagons, partly as green and rosy brown flakes; sometimes also they are half pale green half pinkish brown in the same flake or they may even be partially discoloured. The axial angle varies from 0° to about 15°. (Yellow to yellowish-brown partly altered biotite also occurs in insignificant amounts, as in most samples from the Makassar strait). The appearance of fresh biotite is accompanied by the presence of equally fresh, clear sanidine, plagioclase, strongly pleochroitic green hornblende and apatite. The glass content of the samples is small. This combination of minerals corresponds to the recent products of the volcano Oena-Oena, which lies in the gulf of Tomini.

The only eruption known of the Oena-Oena took place in 1898, and has been described by Wichmann (180). From April to August violent outbursts took place at intervals. The inhabitants fled and during the violent eruptions the island was unapproachable on account of the showers of ashes and ejected stones. It is known for certain that in the eruption of June 19th and 20th ejected ash, reached the east coast of Borneo in the night of June 26th to 27th. Fresh outbursts followed on Aug. 1st, 5th and 7th, when the ashes were again carried to Borneo and penetrated far inland. Wichmann has given a map with the distribution of the ash, showing that it only occurred in a westerly direction so that in Posso, for instance, no volcanic ash fell.

Wichmann found that the eruption products of the Oena-Oena contain plagioclase, sanidine, biotite, green hornblende and a very little augite and traces of iron ore as well as biotite-andesite and biotite-hornblende-andesite particles, while apatite occurs in inclusions. The ash contains no volcanic glass and no gas inclusions, so that Wichmann assumes that it was not a spraying of liquid magma, but an ejection of material which had been altered by a prolonged solfatara action; while Koperberg (92) considers a scattering of a crystallised magma to be possible. The pumice consisted of hornblende-biotite-andesite with glass inclusions in the plagioclase and of augite-andesite with pale yellowish green augite.

Koperberg (Part II, p. 278) found no augite-andesite-pumice in the ash samples he collected personally in 1900, but he did find individuals of apatite rods and apart from that the same composition as Wichmann.

Miss Koomans (90) has determined a rock sample from the Oena-Oena taken by Umbgrove in 1928, which contained phenocrysts of zonal plagioclase, biotite and hornblende in an extremely fine groundmass, with accessory iron ore and apatite; there are also inclusions.

The admixture of volcanic material in samples 41, 40, 39 (and 39a) corresponds to the composition of the volcanic ash of the Oena-Oena, as defined by Koperberg.

The same material was met with, in smaller quantities, in sample 43 and sporadically in samples 38 and 37.

The Oena-Oena ash is only present as distinct ash layers in sediment 41 (see the description of this sample by Kuenen in Table 2) namely at 2—3 cm and 10—11 cm depth. This sample contains the greatest amount of volcanic ash, considering its mineralogical and mechanical composition, it amounts to about 10—15%.

The mechanical analyses of samples 41, 40 and 39 (fig. 12) show a considerable resemblance to those of the Terrigenous Mud 47. The peak in fraction 50—20 μ is due both to the presence of volcanic ash and terrigenous components, as may be seen from this correspondence and the mineralogical composition.

If the distribution of the Oena-Oena ash, as given by Wichmann, be compared with the results from the mineralogical examination of the sediments in the Makassar Strait, it will be seen that all the samples in which this ash is found lie within the area indicated by Wichmann.

Böggild (8) says nothing of the presence of volcanic ash in samples S. 83, 84, 85, 87 and 88 of the Siboga-expedition, drawn from this region. The reason of this probably lies in the method of research which he applied and in the almost complete absence of glass in the Oena-Oena ash.

In sediments 44 and 45 of the Snellius-expedition no recent-volcanic material was found; at

this point only the limit of the distribution region of the Oena-Oena ash lies probably somewhat more southerly than Wichmann has marked it.

The distribution of the Oena-Oena ash seems to have been greater in the west-south-westerly and in westerly direction than to the west-north-west, as is plainly seen on the map showing the distribution.

To summarize, it may be remarked concerning the formation of Volcanic Mud in the eastern East Indian Archipelago that both aeolian distribution of ash and the transport of volcanic material by strong marine currents prove to be important factors. The sediments in the area of Volcanic Mud may vary greatly vertically in composition, as could be seen in sediments 180, 245, 345 and 347 for instance. It is clear that, according to the eruptive activity of the volcanoes, the composition of the sediments varies; this variation may be expressed both in the proportion of the minerals and clay components and in the variation of the mineralogical composition. The variety in a vertical direction of the Volcanic Muds is most obvious where aeolian scattering of volcanic ash has taken place at a moderate distance from the volcano.

The settling velocity of Volcanic Mud is high and varies very greatly, as may be deduced from the above.

2. TERRIGENOUS MUDS

Terrigenous Muds contribute an important part to the sediments in the eastern Netherlands Indian Archipelago, as may be seen from plate I. Here terrigenous material is by far the most widely spread, as besides in deposits of purely terrigenous detritus, it is found in deposits mixed with volcanic ash and in most of the Globigerina Ooze; less often and in smaller quantities terrigenous components are contained in the Coral Sand and Mud.

The terrigenous admixture in other sediments will be dealt with, as far as possible, in connection with that in Terrigenous Muds. In how far this is feasable is determined, but at the same time limited, by the results of the mineralogical examination. As has been shown in Chaps. II and VI, terrigenous admixture may be confined to the finest fractions of the sediment (e.g. in 194). In such cases only by röntgenographic examination the nature of the admixture can be determined, although the fact that terrigenous material is present may have been indicated by the mechanical composition of the samples.

Here it must be emphasized that both in the sediments mixed with terrigenous material and in the Terrigenous Muds, the finest components of the samples may be of a different origin to the sand-fractions, as the distance that these minute particles may travel before settling is practically unlimited.

Before proceeding to the classification of the Terrigenous Muds we will deal with the properties of the minerals found in them.

The minerals

Plagioclase is divided in the tables into group I and II. Group I includes principally bytownite to labradorite, which may be idiomorphic or appear as angular fragments. The idiomorphic plagioclase is often zonally structured; it also occurs in the form of laths. Inclusions of volcanic glass, iron ores, pyroxenes and hornblendes were observed.

Group II includes chiefly andesine to seldom idiomorphic oligoclase; a certain amount of albite could be demonstrated in 229, 364A, 40, 145 and 265, using liquids with an R.I. of 1.525 and of 1.535, which distinguished the albite on the one hand from orthoclase and on the other from oligoclase.

Plagioclase with aggregate structure occurs in 191B and 192.

Sanidine as translucent laths or splinters is found in the alkaline rock detritus, in old-volcanic sediments in the north-eastern part of the Indian Archipelago and in the samples containing Oena-Oena ash from Makassar Strait; it is also found combined with orthoclase in the samples from the Gulf of Boni (188, 189, 191, 190 and 192).

Orthoclase is found as angular or slightly rounded, sometimes slightly turbid fragments in subordinate quantities.

Leucite is described with the alkaline rocks.

Quartz occurs in four forms, namely as:

a. translucent angular fragments of volcanic quartz which sometimes has air bubbles as inclusions; this form occurs very often, but is seldom idiomorphic (in 133 and 337, and a few crystals in 145 and 146).

b. usually translucent quartz of aggregate structure, which shows less or more undulose extinction (191B, 192, 253, 360, 210, 87, 119, 265).

c. quartz containing a certain number of inclusions which appear as dark spots and are sometimes arranged in curved lines. This quartz occurs as angular, sometimes slightly rounded fragments. The inclusions are usually unrecognisable. In the sediments rich in quartz especially the quartz is often framed in a pale green mica-like substance. Sample 80 contains tourmaline-bearing quartz.

d. chalcedony occurs in radiolarites and in siliceous rocks with a fibroradiate structure.

Volcanic glass often of porous structure, with many inclusions and air bubbles, often showing flow structure is a part of the recent-volcanic deposits; it is dealt with in the Volcanic Muds. The inclusions of small leucite ikositetrahedrons in brown glass of the volcanic ash from the Batoe Tara should be specially mentioned.

The presence of *small* quantities of volcanic glass in Terrigenous Muds is to be attributed to the widespreading aeolian distribution of this light material during volcanic eruptions and later by currents in the water of the basins during the period of sinking: its occurence then is unconnected with the other minerals in the sample.

The volcanic glass in the Terrigenous Muds 209, 212, 214 and the upper layers of 331 and 218 has a peculiar appearance. It is dark green glass enclosing elongated laths of augite (extinction angle 40°—45°) which may form crosses or radiating clusters; there are a fewer number of globular inclusions of a colourless isotropic substance.

The glass of old-volcanic material presents the same appearance in various samples, it is structureless and colourless, and contains no air bubbles; the inclusions consist chiefly of plagioclase and often minute undeterminable needles (247, 369, 373, 374, 376, 377, 161, 162, 253A, 361, 80).

Monoclinic pyroxene is seldom idiomorphic in the Terrigenous Muds, but common green augite occurs sporadically, usually contained in glass. Samples 146 and 299 belonging to the group of old-volcanic sediments contain idiomorphic green augite. In the remaining sediments the augite is decomposed to some extent, so that characteristic relict-structures and crystals with ragged ends were frequently observed.

Colourless, pale green, green, yellowish green and violet augite occurs. The pale green and green are usually not pleochroitic. The yellowish green augite is pleochroitic from yellowish green to greyish (blue) green. The titaniferous augite was found in very small quantities in various samples, viz. in 190, 191, 192, 208, 251, 322, 212, 215, 331A, 220, 325, 102, 368, 115, 117, 373, 374H, 376, 377, 159, 155, 154, 126, 382B, 144, 350, 286, 292, 291; in 210 it is rather more frequent. The colour is usually pale violet or pale violet brown; pleochroitic from dull yellowish brown to light or dark violet. No idiomorphic individuals were found; ragged crystals occur.

Rhombic pyroxene displays various habitus in the Terrigenous Muds, in contrast to the hypersthene in young-volcanic rocks. Besides the highly pleochroitic hypersthene a moderately to very faintly pleochroitic bronzite occurs, in a few cases enstatite was demonstrated by its positive sign. In many cases the rhombic pyroxene is distinguished from that of the recent-volcanic rocks by a pale red instead of yellow. Partly alteration and ragged ends were frequently observed. Both in the bronzite and the enstatite striae parallel to the c-axis are sometimes observed.

Enstatite-augite, in which many delicate lamellae of enstatite and monoclinic pyroxene are intergrown, is recognisable by the oblique extinction and by the close longitudinal striae. It is usually colourless, sometimes faintly pleochroitic from yellow to grey-green.

Olivine was shown in twelve Terrigenous Muds, principally in sediments which contained detritus of basic old-volcanic rocks. The olivine appears in very small quantities, as collourless or yellowish green fragments, recognisable by their fairly pronounced birefringence.

Hornblende is found in almost all sediments. Ordinary green hornblende and dark green, highly pleochroitic hornblende with an extinction angle of 15°—20° was met with. Occasionally grass-green hornblende occurred, being pleochroitic from pale yellow through grass-green to green with a tinge of blue, or olive-green hornblende, pleochroitic from yellowish brown to olive-green.

Brown hornblende is fairly common, being moderately to strongly pleochroitic.

Basaltic red hornblende with a small extinction angle is found in subordinate quantities.

Green and red hornblende occur sometimes idiomorphically, which is partly due to some admixture of young-volcanic material. The hornblende in almost all cases, however, is to some extent decomposed, so that ragged ends and fibrous forms occur; yellow-green to green hornblende partly altered into chloritic matter was occasionally met with.

Colourless *tremolite*, prismatic to stringy or fibrous, with an extinction angle of 15° to 16° was found in small quantities.

Actinolite, frequently found in the Terrigenous Muds, occurs in both fibrous and stalky to prismatic forms, unevenly terminated. It is pleochroitic from colourless or pale green to pale bluish green or green with a light blue tint. The extinction angle is about 15°.

Glaucophane occurs in 20 samples, usually in small quantities, it is probably always derived from crystalline schists. In the sediments of the Bay of Boni a remarkable amount of glaucophane is accompanied by considerable quantities of chloritoid. The glaucophane is characterised by beautiful colours, pale yellow $<$ violet $=$ blue, by a small extinction angle, and by its negative sign.

Chloritoid, except in the Bay of Boni, is only represented at St. 80 and St. 376. It consists of irregular greyish green to blue flakes, optically positive and with a small optic axial angle.

Biotite, is general in the terrigenous sediments; in idiomorphic, sometimes sexangular forms as well as in irregularly outlined flakes, partly altered and bleached to some extent. Highly pleochroitic blood-red, reddish brown, orange, darkbrown and golden brown biotite is found as well as faintly pleochroitic green and greenish brown biotite. The much altered biotite is either faintly pleochroitic, yellow, yellowish brown or green, or it is almost colourless without pleochroism. It is optically negative, the optic axial angle varies between 0° and 15°.

Muscovite occurs in very contrasting quantities in a great number of sediments, that is to say as flakes larger than 20 μ; in the finer fractions the results of the rõntgenographic research indicate that the distribution may be even greater. It is present as colourless, occasionally pale green flakes, colourless aggregates do not often occur in the fractions greater than 20 μ. The muscovite may be entirely translucent; but inclusions of carbon particles are equally common, sometimes in such quantities that they render the muscovite completely opaque. Here and there yellow rutile needles were observed in the muscovite.

Chlorite is very common, but never occurs in large quantities. It may be found as very pale green to green plates with low birefringence, being biaxial, either positive or negative, and may be decomposed to a greater or lesser degree. A second form in which chlorite occurs, is that of yellow, yellowish brown or green fibroradiate aggregates with both positive and negative sign of the fibres. Finally there may be „chloritic matter", which appears as colourless, pale yellow or light green flakes or aggregate flakes, formed by the alteration of basic volcanic rocks. They are partially isotropic.

Serpentine occurs in the sediments east, north and northwest of Halmaheira, derived chiefly from old-volcanic material, in fibrous often curved forms. It was further met with at stations 326, 355, 257, 227, 80, 364A. The colour is usually green, bluish green or yellow, but red, pink, violet, pale blue, colourless and partly colourless serpentine also occurs. Pleochroism from pale yellow to light brown or red-brown or to violet was observed. Fibroradiate aggregates also occur. Sometimes fragments of olivine and rhombic pyroxene may be observed in the serpentine.

Apatite is frequently found as inclusions in the minerals of the volcanic rocks (especially in plagioclase and pyroxenes) in the form of idiomorphic, colourless prisms or needles; in suchs cases the apatite is not given separately in the tables. In sediments containing some amount of recent-volcanic material idiomorphic apatite with glass rims was found. Short, rounded prismatic grains of apatite, with minute undefinable inclusions which give the apatite a dusty appearance, seem to be derived from alkaline rocks.

Epidote and zoisite occur in very small to moderate amounts in most of the Terrigenous Muds. They form prismatic grains or angular, occasionally somewhat rounded fragments. The epidote is pleochroitic from colourless or light yellow to greenish yellow. The zoisite displays a blue interference colour. In samples 355 and 111 the epidote was much altered and turbid.

Piedmontite is found in traces in sediment 40, 208 and 120. This manganese epidote is conspicuous by its colour and strong pleochroism of

$a < b < c$

pale yellow—pink—carmine red

Orthite, a cerium-bearing epidote, is found sporadically in samples 208, 358, 322, 94, 278 and 260. The orthite is highly pleochroitic from yellowish green to deep brownish red; prismatic, non-idiomorphic forms occur.

Kyanite was found in very small quantities in sample 191B, while traces of it are seen in sediments 208, 210, 355, 155 and 158. The kyanite is colourless or with a faint blue tint, short or long prismatic with a characteristic cleavage at right angles to the length of the grain, and with an oblique extinction angle up to about 30°.

Staurolite is found as irregular grains, pleochroitic from colourless to lemon-yellow or pale greenish yellow. Traces or minute quantities of it are found in samples 201, 210, 251, 231, 358, 322, 91, 92, 93, 227, 80, 333, 364A, 370, 376, 377, 126; in sediment 255 only, the staurolite is somewhat more frequent.

In sediment 210 only, staurolite occurs in conjunction with kyanite. Druif (44), in his mineralogical examination of the soil in Deli, also found that, contrary to experience in Europe, kyanite and staurolite are usually not found together. He pointed out that in the description of the rocks in Netherlands India the combination of kyanite staurolite is exceptional.

Andalusite was only found in sample 93; its colour is pink, and it is faintly pleochroitic.

Zircon is found fairly universally in very small quantities; it was most observed in the heavy minerals of the sediments rich in quartz. Usually idiomorphic and less or more well rounded zircon occur together; in the sediments derived from volcanic rocks, however, all the zircon is usually idiomorphic. The mineral is usually colourless; but in samples 191B, 39, 305, 210, 260, 280, 355, 91, 103 and 110 pink, faintly pleochroitic zircon is found beside the colourless; blue to violet zircon was found only in sample 214.

Tourmaline is most strongly represented in the sediments which consist chiefly of detritus of crystalline schists. In some of the sediments rich in quartz and poor in heavy minerals the tourmaline content is comparatively high. In the detritus of volcanic rocks it is practically not found. The mineral is partly almost idiomorphic, those forms which are not idiomorphic vary from slightly rounded prisms to much rounded off grains. Green and brown tourmaline, pleochroitic from colourless to pale green or green and from colourless to yellow or light brown or from light to dark brown, predominate. To a smaller extent blue tourmaline, pleochroitic from colourless to blue is found. Sometimes blue and brown are found in the same grain. Further the following colours occur:

pale yellow to brownish green
pale yellow to orange-brown
colourless to grey
colourless to blue-green
pale violet to greyish blue
brownish violet to black
violet to dark blue.

Garnet, like tourmaline, was mostly found in crystalline schists; the mineral, apart from that, is generally distributed in small quantities in the sediments. The colour is usually pale pink or pink, to a less extent colourless garnet is found, usually beside the coloured mineral: very occasionally pale green garnet was found. The crystals are more or less rounded and isotropic.

Titanite, as an accessory mineral, occurs in a comparatively large number of sediments; as colourless or yellowish green irregular grains with a very high refractive index and birefringence and very strong axial dispersion, usually well seen in the interference figure with coloured isogyres.

Rutile and *Brookite* are found in very small quantities in some of the sediments which contain detritus from crystalline schists, acid igneous rocks or quartziferous sediments. They are absent from the detritus of recent as well as basic old-volcanic rocks. Both minerals occur as non-idiomorphic crystals with a diameter of less than 0.1 mm, in sediment 158 only, larger individuals are found.

The rutile is pleochroitic from bright yellow to yellowish brown, or from golden yellow to golden brown or brownish red. It is also much found as inclusions in quartz, usually as extremely delicate needles, occasionally as thicker yellow needles. In the sediments from St. 191 beautiful idiomorphic, prismatic or needle-shaped rutile occurs, both independantly and as inclusions in muscovite.

The brookite occurs sporadically beside the rutile. The mineral shows yellow and green colours and is characterised by striae on (100).

Anatase was found sporadically in a few sediments (251, 360, 358, 215, 216, 210, 26, 100, 101, 102 and 247) as yellow or light brown crystals only. It is usually idiomorphic, often bipyramidale, showing striations parallel to intersection with prism; tabular grains are also found.

Chromite and *picotite* occur in a comparatively large number of samples in very small quantities. They are found as dark brown, red-brown, green-brown, coffee-brown and yellow-brown irregular fragments, seldom as rounded octahedral grains.

Magnetite and *ilmenite* are found in very varying amounts in most of the sediments, often in idiomorphic forms.

Zeolites were found in a limited number of samples, principally in sediments which contained basic volcanic material. The highest content of zeolite is in sediment 264. We could distinguish:

Analcite in rounded forms; the refractive index varies between about 1.48 and 1.49, the birefringence is sometimes very faint, the analcite is often entirely isotropic. The zeolite was demonstrated in samples 35, 33A and 186, which contain detritus from alkali rocks, and in samples 260, 271, 268, 265, 264, 261 and 262, which contain detritus of basic and ultrabasic igneous rocks.

Laumontite occurs as somewhat fibrous or platy aggregates with a refractive index from 1.51 to 1.523. The birefringence is higher than that of quartz and conspicuously higher than that of the other zeolites found. Laumontite is colourless, shows undulose extinction with an angle of extinction up to 45° and is optically biaxial negative, to pseudo-uniaxial. This zeolite was found in sediments 261, 262, 264, 265, 268, 260, 271 and 80.

The other zeolites usually form fibroradiate aggregates with a low refractive index and low birefringence and with both positive and negative length of the fibres.

It is possible that a part of the analcite is formed in the sea, perhaps from leucite.

Secondary minerals

Pyrite, in greatly varying quantities is very general in the Terrigenous Muds and in the deposits mixed with Terrigenous Mud.

Usually the pyrite is found as brownish black globules, which occur both separately and in aggregates. The aggregates partly still fill the chambers of Foraminifera and other organisms. When the calcium carbonate shells of these organisms are dissolved or broken they are released. Pyrite globules occur less frequently in or upon Radiolaria. They remain intact when treated with hydrochloric acid, and they belong to the heavy crop, like the yellow pyrite with metallic lustre. The latter is rare, only met with in 87, 88, 106A, 119, 257 and 328; it shows distinct, although sometimes very small, crystal surfaces.

In a few cases pyrite globules formed the nucleus of clay casts, in other the pyrite had a limonite sheath. In sample 328 it was found as the nucleus of a ferrugenous pellet, which had a cover of manganese-oxides.

Barite is found only in sediments 87 and 88 with pyrite, as sharply angular fragments or prismatic grains, optically biaxial positive.

Glauconite occurs as green earthy grains, which show an aggregate polarisation, occasionally as grains coloured yellowish green by limonite; they fill the chambers of Foraminifera and other organisms. In the glauconite which occurs separately the form of the chambers of Foraminifera can sometimes be recognised. The most frequent dimensions of the glauconite grains are 0.1—0.5 mm which occurs especially with a high glauconite content in the sediment; low glauconite contents, which may be attributed to glauconite transport usually have smaller dimensions.

Glauconite is especially found in the sediments of the Ceram-Timor outer arc and the adjacent eastern Halmaheira sea, further up and near the Soenda shelf and north of Soemba.

Limonitic casts are the filling of Foraminifera etc., consisting largely of yellow to red and brown hydrated ferric-oxide, which are found both in and outside the organisms in the sediments. In some of the limonite no outline is to be seen, this flaky material forms a subordinate part. Limonite occurs sometimes also in the clay casts of the Foraminifera as dots or veins or on the fracture surfaces.

The sandy material, of which most arenaceous Foraminifera consist, is often cemented by limonite-containing material.

Clay casts are pale grey, grey, grey-green, green or yellowish brown clay aggregates, usually

discs, which occur in Foraminifera, or remain after the shells have been dissolved. The clay casts are not disintegrated by Mohr's mechanical analysis. They do not fall to pieces at treatment with diluted hydrochloric acid, they may or may not contain some calcium carbonate. In one specimen, viz sample 73, the clay casts have a green colour due to glauconite; the structure of the clay casts in polarised light sometimes indicates the presence of chlorite or serpentine-like material with a green colour, as in samples 343, 280, 279, 278, 271. Yellowish brown clay casts contain limonite.

The röntgenographic examination of the clay casts of five different sediments demonstrated that they actually were composed of adhering clay particles. Table 27 in Chap. VI shows that the composition of the clay casts, which were 0.5—1 mm in size, corresponds best to the composition of fraction 0.5—2 μ of each sediment, or the composition lies between that of fractions 2—5 μ and smaller than 0.5 μ. They consist principally of montmorillonite, kaolinite, muscovite and quartz, in which the proportion changes with the composition of the clay fractions of the sediment in which they occur; moreover calcite and felspar may or may not be present.

Mineral „X". In the heavy crop of 17 samples from the Cream-Timor-outer arc, a mineral with a refractive index of 1.63—1.64 was found, which could not be identified. This mineral is faintly pleochroitic from very pale yellow to yellow, it consists mostly of fibres which extinguish parallel to length of fibres. The fibres often form radiating clusters, the length of fibres is always positive. The fibroradiate aggregates sometimes show the shape of chambers of Globigerina. In the preparations which were not treated with hydrochloric acid the mineral was never found, so that it must be assumed that it was formed in the organisms. This mineral occurs sporadically in the sediments, the most is found in sample 88. A small quantity could be separated from this sample. Silicic acid, much aluminium, sodium and a little magnesium were found microchemically; phosphate proved to be completely absent. The mineral is, therefore, probably a slightly magnesium-bearing sodium-aluminium-silicate. (There was not sufficient material for the reaction to barium and iron.)

Mineral „X" usually occurs with glauconite, so that the question arises of whether it might be an intermediary product in the formation of glauconite.

Calcite and dolomite may both occur as secondary mineral, viz. as good idiomorphic simple rhomboedra, which are occasionally slightly rounded (in 218A). They were mostly found in fraction 50-20 μ (and smaller), in fraction 100-50 μ they are more rare. No inclusions were found. The content of this secondary calcite and dolomite is usually small, it varies from a trace to 0.3%, calculated for the whole sample. In samples 354A and 375 only, the content is higher. In sediment 375 the rhomboedra proved to consist practically only of calcite (they dissolve rapidly in cold diluted hydrochloric acid).

These secondary formations of calcite and dolomite occur chiefly in the sediments from the Ceram-Timor-outer arc, in the Ceram sea, in the south eastern half of the Sawoe sea and further locally near the coast.

CLASSIFICATION OF THE TERRIGENOUS MUDS

The classification of Terrigenous Muds according to the derivation of the material yielded by the mineralogical examination, meets with more difficulties than in the case of the Volcanic Muds, because:

1. Terrigenous Muds are often very fine sediments, in contrast to Volcanic Muds a mineralogical examination of the sand fractions only of these fine samples, is not sufficient to determine them.
2. Not enough is known of the geology, and of the petrographic composition of the surrounding islands.
3. The number of samples in proportion to the extent of the area examined is small.

It follows from the above that the coarser sediments, that is in general the sediments which are deposited not far from the coasts of the large islands, are the least difficult to recognise and classify according to the material.

For the above reasons the Terrigenous Muds can only be classified roughly in general groups. These groups are as follows:

I. Sediments which consist of detritus of crystalline schists (and phyllites) and a small amount of acid igneous rocks, either metamorphosed of not.

II. Sediments composed chiefly of detritus of acid igneous rocks with a small amount of material of crystalline schists.

III. Sediments which consist principally of detritus of intermediate to basic metamorphic rocks, with or without old basic eruptive rocks.

a. with a predominance of actinolite

b. with a predominance of epidote.

IV. Sediments which contain chiefly detritus of quartziferous sediments.

V. Sediments which consist chiefly of detritus of basic old-volcanic rocks.

a. Sediments derived from detritus of alkaline rocks.

b. Sediments consisting of detritus of calc-alkaline rocks.

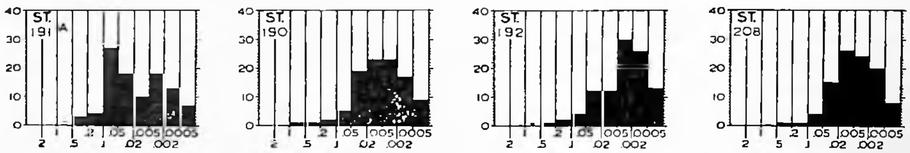
On Plate I, which gives the distribution of the various sediments, the Terrigenous Muds, coloured blue, are classified according to the above groups and marked with different shadings. The shading, in so far as justified by the mineralogical composition, is continued in the area of the Terrigenous + Volcanic Muds and the Globigerina Oozes: this indicates that in these sediments the admixture of terrigenous material corresponds to that of certain neighbouring Terrigenous Muds.

I. Terrigenous Muds consisting of detritus from crystalline schists (and phyllites) with a little acid igneous rocks, metamorphosed or not

These Terrigenous Muds are characterized by the high mica content of the minerals (minerals being the total amount of minerals reduced by the content of secondary minerals such as limonite, clay casts etc.) and by a relatively high content of heavy minerals in garnet and tourmaline or one of them, or in some cases in glaucophane and chloritoid.

The Terrigenous Muds belonging to this group occur in the Bay of Boni (191A—191B, 190 and 192), to the north east of the Toekang Besi islands (208), to the south of Boeroe (250, 251, 255), of Ambon (231, 232, 233) and of Ceram (360, 358) and along the series of Ceram-Timor islands in the Weber-deep: to the south west of the island of Manawoko (322), in the east of the volcanic island Manoek (362) and north of the Tenimber islands (364).

Of the samples raised near the south east arm of Celebes the mineralogical composition is given in table 12, the mechanical analyses are graphically represented in fig. 13.



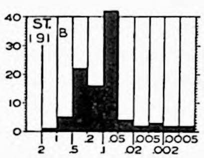


Fig. 13. Mechanical Analyses of Terrignous Muds, near the S.E. arm of Celebes (Group I).

The difference in mechanical composition of the upper and lower layers of the 26 cm long sample 191 is very striking: the upper layer contains some 40% of clay, while the clay percentage of the lower layer does not amount to 10%. In the Gulf of Boni so many rivers debouch that a considerable clay content would be expected in the sediments, especially as strong currents are not probable in this gently shelving inland sea. The absence of clay casts and the small amount of clay in the lower stratum 191B may indicate that this layer represents a land slide. In the other Terrigenous Muds from the Gulf of Boni, 190 and 192 there is no sandy bottom layer, the mean grain-size diminishes from 191A via 190 to 192, thus from north to south.

The mineralogical composition of the two layers 191A and 191B also show a difference. The coarser sandy portion of 191B with a peak in fraction 0,5—0,2 mm, contains many rock particles, including phyllites, much quartz and plagioclase showing aggregate structure, much green and pale

TABLE 12. Mineralogical Composition of Terrigenous Muds, near the

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green hornblende	red hornbelnde	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite and serpentine	epidote and zoisite	piedmontite	orthite	kyanite	zircon	tourmaline
191A	2	5	4	3		1											2							
	3	7	11	7	0,2	0,5		tr.						tr.			17	2						
	4	3	9	7	0,2	1									0,2	0,1	28	1						
	5	1	9	12	tr.	5	tr.	tr.	0,5	0,5		0,2	0,5	0,5	0,5	1	44	1	1				0,2	0,5
	6																							
191B	1	43		16	4	17																		
	2	41		18	3	27		1	0,5							0,5	0,5							
	3	20	5	9	1	8		5	0,5	tr.					0,3	7	35	3						
	4	7	10	20	0,1	14		1	tr.	0,1					2	1	35	1	1					0,1
	5	2	8	20	0,1	14		0,2		0,3		0,5	0,5	tr.	2	1	30	1	2			0,1	0,5	0,5
	6																							
190	2																							
	3																							
	4																4	tr.						
	5		2	8	0,1	4	0,1	0,2		0,5		tr.	0,1	1	0,2	0,5	5	2	1				0,1	tr.
	6																							
192	2																							
	3		0,2	0,6		0,2										tr.	3							
	4	2	2	6	0,1	3		tr.		tr.					0,3	tr.	7	0,5						
	5		2	7	0,1	4	tr.	tr.	tr.	0,3		tr.		0,3	0,3	0,3	5	1	0,5				tr.	0,1
	6																							
208	2																							
	3						0,1																	
	4	1		0,5			0,5										0,5							
	5	1,5	5	8		1	0,1	0,2	0,1	0,1	tr.	tr.	0,1			tr.	8	0,1	0,1	tr.	tr.	tr.	0,2	tr.
	6																							

green monoclinic pyroxene and little highly pleochroitic hypersthene. In 191A, on the other hand, no highly pleochroitic hypersthene is found and practically no monoclinic pyroxene, while the content of rock particles, plagioclase and quartz is lower, the latter, moreover, showing no aggregate polarisation. Both layers have a high content of muscovite which sometimes includes yellow rutile needles. The medium fractions (200-20 μ), which are strongly represented in both strata, show more resemblance although 191B contains relatively more chloritoid and much less glaucophane than 191A, and the rhombic pyroxene of the upper layer of 191A, in contrast to the lower layer, is very faintly pleochroitic. The quartz in the medium fractions is in both layers translucent and angular, seldom turbid. In both layers yellowish brown and green biotite occur, in 191B, moreover, there is pink and blood-red biotite.

With regard to the derivation of the material in sediment 191 it may be remarked that the neighbouring steep west coast of the S.E. arm of Celebes, consists chiefly of crystalline schists, according to Dieckmann and Julius (42) containing blocks of basic igneous rocks near La Pao Pao and Tandjong Pakar, while the Padamarang islands, lying in the Mengkoka bay, also consist of basic igneous rocks. In the crystalline schists they found: phyllites, quartz-mica-slate and mica-bearing quartzites, while amphibolites, chlorite- and sericite-schists occur to a lesser extent. The amphibolites contained both glaucophane and actinolite.

Gisolf (60) described from this region of crystalline schists: phyllites, ottrelite-bearing phyllite, ottrelite-phyllite (rutile and tourmaline bearing) and mica schists (containing zircon).

Wunderlin (190) describes from the more southern area, the Gg. Mendoka lying to the east of Tandjong Pakar, crystalline schists as: glaucophane-bearing graphite-mica-schists (consisting of quartz, muscovite, graphite, glaucophane, garnet, chlorite and serpentine, pyrite and limonite) and amphibolites. Of igneous rocks diorite, gabbro and harzburgite were found, while near Tandjong Pakar a harzburgite altered into serpentine was found.

There is a great resemblance between the composition of the rocks described and that of the sediment at St. 191; detritus of harzburgite, however, was not found in these samples, while detritus of plagioclase-bearing basic rock only occurs in the sand fractions of the lower layer 191B.

S.E. arm of Celebes (Group I).

garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite	pyrite	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Pteropods	Alcyonarian spicules	calcareous Sponges	calcite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
								20	35	58	2							60					5	0,2
							0,2	40	85	8	0,5					1	1	10,5	3	1		4	0,5	2,9
							0,5	35	85	7	tr.		tr.			1		8	1	5		6	1	4,1
0,5		0,2		0,5	0,3		1	6	86	7	0,4	0,1			1	3		11,5	1	1		2	0,5	26,8
					1			6	79						2			16,4	2	2	0,1	4,1	0,5	18,2
									80	4	tr.					4	12	20						0,9
									91,5	6,5						1	1	8,5						5,3
					0,6				94,4	4	tr.					1	0,5	5,5	tr.	tr.		0,1		21,9
0,1				tr.	0,3		1		93,7	3	0,2	tr.				3		6,2	tr.	tr.		0,1		15,8
0,5		0,5		0,5	0,5	0,2	1		85,9	7	0,2	0,2			1	4,6		13	1	tr.		1		41,8
					2				80,5									16	2	0,5		2,5	1	4,2
										99	1							100						0,5
								2	2	97	1							98						1,0
								8	12	79	1	0,5						80,5	1	6		7	0,5	2,2
	tr.	0,1	1	tr.	0,3		tr.	3	29,2	63	1	1			2	1		68	2,5	tr.		2,5	0,3	5,3
					0,5			2	27,5									65	5	2	0,3	7,3	0,2	19,2
								1	1	98	1							99						0,2
					tr.			18	22	75,5	0,5							76		2		2		0,9
					tr.			25	46	49	1	tr.				0,5	0,5	51	1	2		3		1,9
0,1		tr.	tr.	1	0,3	0,3	tr.	18	41	55	1			tr.	tr.	1	0,5	57,5	1	0,5		1,5		4,0
					1			12	52,7									40	5	2		7	0,3	11,9
										92	5							97	3			3		0,2
							tr.	1	1,1	92	4							96	2,4	0,5		2,9		0,6
							0,5	4	7	—75,4—		0,1						75,5	1	16		17	0,5	1,3
0,1	tr.	tr.	tr.	tr.			1	5	31	—65,5—								65,5	1	2		3	0,5	4,4
								6	36									53	4	6	1	11		15,0

The mineralogical composition of 190 and 192 bears the greatest resemblance to that of 191A; these samples also contain a considerable quantity of glaucophane and chloritoid. Moreover chromite and picotite were found most in 190, which points to the presence of detritus from ultrabasic rocks. In 192, as well as in 191B, a small amount of quartz aggregate occurs.

It does not appear that detritus of quaternary corals, which are reported by Dieckmann and Julius as forming the west coast near St. 190, enters into sediment 190. Sediments 190 and 192 are probably both composed of material which was carried south through the Bay of Boni; the decrease in the mean grain-size in the Terrigenous Muds of this bay in a southerly direction is an indication of this, as is the corresponding mineralogical composition of the samples 191A, 190 and 192.

The mineralogical composition of sample 208, taken north east of the Toekang-besi islands on the steep slope of the Banda sea, is distinguished from the other samples in table 12 by the absence of chloritoid and glaucophane and by the presence of traces of orthite and piedmontite. The monoclinic pyroxene in 208 is pale green, colourless or pale violet-brown, the rhombic pyroxene shows the same habitus as that in 191A, 190 and 192.

The mechanical diagram (fig. 13) of sample 208, with a peak in the fraction 20—5 μ is typical of Terrigenous Muds. This diagram occurs in 22 of the 107 Terrigenous Muds of which a mechanical analysis was made; it occurs in three of the Volcanic + Terrigenous Muds, while the mechanical composition is never found in Volcanic Muds, Coral Muds and Globigerina Oozes; sample 189B is still of the same mechanical composition being a transition of Globigerina Ooze to Terrigenous Mud containing much calcareous debri.

Concerning the derivation of the material in 208 it can only be said that crystalline schists and basic to ultrabasic eruptive rocks occur both in North Boeton and Wawoni and in the region around Kendari on S.E. Celebes (see bibl. 9). Rocks containing piedmontite especially piedmontite-phyllite and piedmontite-quartzite have so far only been described by Gisolf (60) from the northern part of the S.E. arm of Celebes. He found orthite in a biotite-hornblende-granite in the S.E. part of Mid Celebes, which adjoins the S.E. arm; he found much more orthite in rocks from Mid Celebes (59).

The mineralogical analyses of the further sediments belonging to group I, together with those of sediments 253^L and 361 lying near them, consisting of old-volcanic material, are given in table 13; the mechanical analyses of these sediments are given in fig. 14.

These sediments lie in the seas to the south of Boeroe and Ceram and in the Weber Deep.

The mechanical analyses of sediment 251 and 255 (this applies also to 210) taken south of Boeroe are of about the same composition as that of sample 253^L, taken close to the coast of Ambon. The observations by the Snellius-expedition show strong currents near the south and east coast of Boeroe, which is confirmed by the composition which Dr. Kuenen gives for samples 211 (pebbles and corals), 252 (pebbles), 253 („trace" of clay), 256 (pebbles with coating of manganese) and 230 (pebbles, pumice and shells) (see photo 2—4). Owing to these strong currents only pebbles can be deposited in the vicinity of the south and east coast of Boeroe while the fine sand fractions, which are usually deposited to a great extent near the coast, can only settle at a greater distance (20—50 km).

The mineralogical composition of samples 251 and 255 is remarkable both from its high mica content and the high content of garnet as well as from the presence of staurolite in quantities which amount to 3% and 19% of the heavy minerals. Amongst the rock particles of 255 mica schists can be recognised. The quartz in these samples is angular and both translucent and turbid. Some of the biotite is greatly decomposed, bleached and slightly turbid, partly markedly pleochroitic, orange-brown and golden brown. The muscovite contains many carbon particles as inclusion. The monoclinic pyroxene of 251 is partly titaniferous augite (as in 210), partly colourless or pale green. The rhombic pyroxene of 251 is faintly pleochroitic, in 255 it is highly pleochroitic and coated with volcanic glass.

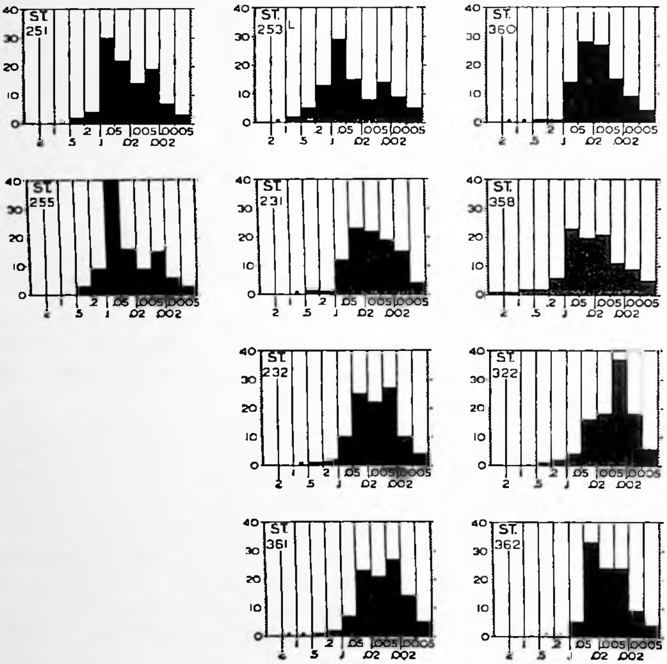


Fig. 14. Mechanical Analyses of Terrigenous Muds, deposited South of Boeroe and Ceram and in the Weber-Deep (Group I).

The mineral composition of the terrigenous admixture in the Globigerina Ooze 250 corresponds to 251, except that there is no staurolite in 250.

The south coast of Boeroe has only been partially examined, so that only a few general remarks can be made concerning the derivation of the above material:

St. 251 lies in line with the river Wai Tina which runs into the sea at the most southern point of Boeroe. The basin of this river, as far as is known from Deninger's research worked out by Wanner (174), lies for a great part in the sandstone and schist series, reckoned by the Upper Trias in which conglomerates occur containing rounded schist material. More to the east on the shore by Oki and in the river Oki, boulders of sandstone, crystalline schists, clay schists and limestone are found, that is, the same kind of material as in the Wai Tina. West of the area of the Wai Tina Deninger found on the coast of Tandjong Kaboet some leucitite, while Martin met with small amounts of mica-andesite in the neighbourhood of Tifoe and Mefa.

It is probable that the rivers running into the sea on the south coast of Boeroe have contributed a large part of the terrigenous components of sediments 251 and 250.

From the S.E. part of Boeroe, where St. 255 lies, hardly anything is known. From the collection of rocks by Martin, which Schroeder van der Kolk handled, we know only that in the area south of Kajeli crystalline schists, the Trias sandstone- and schist-series and Trias limestone occur. The composition of sample 255 indicates an admixture of detritus of igneous rocks.

Samples 231, 232 and 233, taken to the south of Ambon, belong to group I, however, in all three samples the old-volcanic material occurs of which sample 253^L chiefly consists, also a little recent volcanic material. The principle component of this sediment is formed by detritus of mica-schists, of which the mean grain-size diminishes towards the south.

The derivation of the schist material, which must therefore have come from the north, cannot be looked for on Ambon or the Oeliassers, where only fragments of mica-schists were found. It must have come from the southern part of West Ceram or even from Manipa, where crsytalline schists are very prominent. In the opinion of Rutten and Hotz (136) and also Rittmann (132) the crystalline schists on Manipa are principally mica-schists, petrographically corresponding to those in the Wallace mountains. On the Hoeamoal peninsular and north of the Wallace mountains in West Ceram many phyllites and mica-schists were found, while quartzites, amphibolites, green schists, garnet-mica-schists etc. also occur. North west of the Wallace mountains phyllites predominate.

The old-volcanic material of these samples can best be treated in connection with sediment 253^L.

Sample 253^L contains a remarkable amount of practically colourless glass, which often encloses extremely delicate needles (possibly pyroxenes), sometimes a little plagioclase, faintly pleochroitic rhombic pyroxene or colourless augite are enclosed.

The rock particles in all four samples are both andesites rich in glass and mica-schistlike rock. The plagioclase often encloses glass. The quartz is translucent and angular, although, more rounded quartz, exhibiting undulose extinction, is also met with. The muscovite may be either transparent, or rendered quite opaque by enclosed carbon particles. The biotite is brown or green and occurs both in idiomorphic and much altered flakes.

St. 253^L lies near the S.E. point of the Leitimor peninsular of Ambon of which Verbeek (167) constructed a geological map. In the eastern part of the peninsular he found younger igneous rocks, viz. bronzite-andesite and -dacite, biotite-andesite and -dacite, glass rocks, melafier with glass and a little liparite. South and west of these igneous rocks sandstone with claystone and limestone banks occur, as well as chlorite rock, serpentine-muscovite rock and serpentine breccia. The sandstone, as reported by Verbeek, consists chiefly of granite grit; according to Brouwer and Rutten (142) it may be gneiss and mica-schist debris. From Tandjong Hoetoemoen, the S.E. point of Leitimor, northwards, coral rock moreover is found. The Wai Sermeti, which enters the sea west of Tandjong Hoetoemoen as the Ajer Besar, originates chiefly in the area of younger eruptive rocks, while some contribution of material from the sandstone area is possible; it further cleaves a strip of hard diabase rock, which according to Verbeek consists of quartz, plagioclase, augite and ilmenite, with chlorite, calcite and leucoxene as alteration products.

The composition of sediment 253^L corresponds in general with the bronzite-andesite and -dacite, often very rich in glass, and biotite-andesite and -dacite of E. Leitimor, described by Verbeek, which may contain quartz, plagioclase, bronzite, biotite, chlorite (secondary), apatite and a little hornblende. As inclusions in these rocks cordierite and garnet may be found amongst others; cordierite however, has not been observed in 253^L, garnet has been found sporadically, which may equally well have come from schists. Possibly detritus from diabase is present. The calcite and calcareous debri in sample 253^L may be derived from limestone banks or from coral rock from Leitimor, or have been formed secondarily in rocks; in all these cases they should be regarded as terrigenous material. Consequently, although the calcium carbonate is rather more than 30%, sediment 253^L is understood to be a Terrigenous Mud, composed chiefly of detritus from younger (but not recent) eruptive rocks from Ambon, to which has been added in smaller quantities detritus of diabase, sandstone, limestone and coral reefs.

The material of these eruptive rocks was found moreover in diminishing quantities in sediments 231, 232, 233 and 234; it also occurs in sample 361.

Sediment 361 (see table 13), however, according to the mineralogical examination, is composed chiefly of detritus of hornblende-andesite and -dacite and of biotite-andesite and -dacite. The colourless volcanic glass in this sample may include yellowish brown to dark green pleochroitic horn-

TABLE 13. Mineralogical Composition of Terrigenous Muds, deposited south of Boeroe

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	olivine	green and brown hornblende	red hornblende	tremolite	actinolite	biotite	muscovite	chlorite	apatite	epidote and zoisite	orthite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite
251	2																									
	3			9		2									3	24	tr.						tr.			
	4			17	1	14									2	45	0,5									
	5		2	30	1	17	tr.	0,1	0,1		0,1			0,2	1	40	0,5		0,1		0,1	0,2	0,2	1,4	tr.	tr.
	6																									
250	1—5		†	†	†	†	tr.	†	†		†			†	†	††	†		†			†	†	†	tr.	tr.
255	2																									
	3	10	0,5	4		4			0,1		tr.			tr.	11	44								tr.		
	4	12	4	8		8			tr.		0,1				9	50	tr.							0,1		
	5	2	2	20	0,3	12	tr.				0,1	tr.	tr.	0,5	8	45	0,2		0,1		1	0,2	1	2	0,1	tr.
	6																									
231	2																									
	3	4	1	2		0,3	1	tr.	0,5	tr.					tr.		0,1									
	4	8	4	8		5	9		3	0,1				tr.	2,5	2	2		0,2							
	5	1	7	16		9	2	0,3	1		0,1			2	4	22	1	0,3	0,5		tr.	0,2	1	0,5		
	6																									
232	2						2																			
	3						7								0,5											
	4	8	2	4		0,2	11	0,1	0,1	tr.					3	1										
	5	4	6	15		5	6	1	1	tr.	0,3			0,5	10	30	0,2	tr.	0,5			tr.	1	0,3	tr.	
	6																									
233	5	3,5	3	4		3	12	0,5	1,2		0,2			0,2	2	3	0,3	tr.	0,3			tr.	0,1	0,1		
253L	1	†																								
	2						19									1										
	3	0,1	2	0,7		0,5	23								1	2	0,1									
	4	5	2	6		1	27								2	1										
	5	0,4	7	7	tr.	4	11	0,2	1		0,1			0,2	2	0,5	1		0,3			0,2		tr.		
	6																									
361	1	†																								
	2	4					6																			
	3	3	1,5				6																			
	4	8	4				7			tr.	0,2				5											
	5	15	23	2		1	12	0,5	1		6				4	0,5	1	0,5	0,3			0,3		tr.		
	6																									
360	1	10																								
	2	12																								
	3	10	1	1		1		0,1							3	3	0,1							0,1		
	4	10	7	2	tr.				tr.						4	12	0,3		tr.					tr.		
	5	2	7	9	0,1	9					tr.				5	50	0,1	tr.	0,1			0,3	2	0,5	tr.	
	6																									
358	5		7	20	0,2	12	0,5	0,2	0,1		0,3	tr.		0,6	1,5	45	1	tr.	0,7	tr.	tr.	0,1	0,2	0,9	0,1	
322	2																									
	3																									
	4			0,3		0,2										0,5										
	5		2	16		9	0,3	0,3	0,1		0,3	tr.		0,3	1	35	0,1		0,2	tr.	tr.	0,1	0,2	0,2	tr.	
	6																									
362	3																									
	4					2	tr.																			
	5		1	22	tr.	10	0,5				0,1		tr.	2	4	50	0,1		2			tr.	1	1	0,5	
	6																									
364	1—5			0,1	tr.	0,1		tr.	tr.		tr.			tr.		0,2			tr.			tr.		tr.		
	6			2		1			tr.		tr.			0,1	0,2	4							0,1			

blende, colourless augite and faintly pleochroitic rhombic pyroxene. The rock grit is rich in glass. The plagioclase often includes glass and seldom bronzite. The quartz is translucent and angular. The biotite is mostly greenish brown and faintly pleochroitic, partially idiomorphic, some biotites are highly pleochroitic from yellow to orange.

St. 361 lies south east of the Oeliassers.

Kuenen has examined the northern half of Haroekoe (not yet published). He describes the volcanic rocks as liparites, hypersthene-dacite and biotite-dacite, andesites, basalts and gabbro-diorite. In all these rocks practically no hornblende occurs.

Schroeder van der Kolk (147) examined the rocks collected by Martin in the Oeliassers. Chiefly

and Ceram and in the Weber-Deep

anatase	chromite and picotite	magnetite and ilmenite	pyrite	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Pteropods	Ostracode valves	Otoliths of fish	Alcyonarian spicules	calcareous Sponges	Discoasteridae	calcite and dolomite rhomboedra	calcite	undefined calcareous debris	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
						98	98																		2	0,16
					0,5	55	93,5	0,5		tr.				tr.						0,5	3	2		5	1	2,4
					2	16	97,5	0,5												0,5	1	1		2		3,6
tr.		0,3			1	3	98,3	0,3		tr.									0,7	1	0,4	0,3		0,7		29,8
			0,1			2	93,5													2	2	2	0,3	4,3	0,2	21,5
		†			0,5	0,5	31	67	0,2											67,2	0,5	1		1,5	0,3	17,3
						†		†	†												†				†	0,1
						4	77,7	9	0,1	0,2										9,3	8	3		11	2	2,8
						2	93,2	3,7	0,1	tr.										3,8	1	2		3		8,9
		tr.				0,5	95	2	tr.									0,2	0,3	2,5	2	0,5		2,5		39,5
			tr.				94													2,2	2	1	0,3	3,3	0,5	15,5
					4		4	95	1											96						0,35
					2		11	80	4	tr.										84	4	1		5		1,6
					7	1,2	52	44	1											45	2	1		3		1,4
		0,2			2	1	71	24,5	0,5						0,1			0,9		26	2,8	0,2		3		12,2
							82								0,1	tr.				14	3	1		4		23,2
						96	98	1	1											2						0,2
						88	95,5	1	0,5											1,5	1	2		3		0,6
						60	89,4	0,6												0,6	1	9		10		2,1
	tr.	0,1	0,1			14	95	0,5										0,5		1	3	1		4		10,5
			0,1			8	90													1	5	3,5	0,5	9		24,6
						1	34,5	--64---										0,3		64,3	1	0,2		1,2		12,4
													†						†						†	0,4
				0,5			20,5	62	3	1			2						9,5	77,5	2			2		1,6
				0,5		3	33	39	1	1	1	0,5		0,5					13	56	9	1		10	1	5,0
						7	51	--21---		1	2	0,5		0,5					18	43	4	1		5	1	13,2
		0,1				3	38	--18---		0,3				0,1	2			5	32	57,4	4	0,5	tr.	4,5	0,1	28,8
						2	45								2					46,7	7	1	0,2	8,2	0,1	15,2
									†																	0,01
							10	88	2											90						0,3
					tr.	1	11,5	82	3	0,5										85,5	1	2		3		0,6
					0,1	10	34,3	45	0,2											45,2	3	17		20	0,5	1,6
		1			0,4	6	74,5	18										2		20	4	1		5	0,5	7,0
						3	73													17	5	4	0,5	9,5	0,5	22,6
							10		10										40	50					40	0,3
							12	72	3	1									5	81	1			1	6	0,25
							19,3	63	2	0,3				0,3					5	70,6	6	3		9	1,1	0,5
tr.							35,5	43	1	0,3		0,1		1					14	59,4	2	2		4	1,1	0,5
tr.		0,5					85,8	---8---		0,1					0,5				4	12,6	0,8	0,5		1,3	0,3	14,5
							91								0,2		tr.			7	1	0,5	0,2	1,7	0,3	28,3
tr.	tr.	0,5	tr.				91	2										1	5	8	0,5	0,5		1		22,8
						90	90	10												10						0,2
						82	82	--17---												17		1		1		0,9
						61	62	---7---												7	1	30		31	tr.	1,8
	tr.	tr.	0,5			24	89,7	---3---										1		4	2	4		6	0,3	3,8
			tr.			15	82										0,1			10	3	4	0,7	7,7	0,3	16,0
			†		†	†																				0,1
			3		7	67	79	9												9		4		4	8	0,2
		0,5	1		0,5	1	97,3	1										0,5		1,5	0,5	0,2		0,7	0,5	5,2
			1			0,3	96,8													2	0,5	0,2		0,7	0,5	33,2
		tr.			1	0,5	2	95	1	1										97	1			1		95,5
					1	10	18,5	---78---												78	2	1	0,3	3,3	0,2	0,8

younger volcanic rocks were found, which are divided into pyroxene-dacites and biotite-dacites. A rock from the north east coast of Noesa Laoet corresponds qualitatively with the composition of sediment 361, lying south east of the islet. It contains much plagioclase, very little quartz, about the same amount of greenish brown amphibole as rhombic pyroxene and a little biotite, magnetite, zircon and apatite. On Hitoe, the northern part of Ambon, Verbeek (167) later found hornblende-andesite and -dacite. The younger volcanic rocks of Ambon and the Oeliassers resemble each other so much that it is probable that these rocks also occur on the Oeliassers and that it will prove that sediment 361 should be regarded as detritus of effusive rocks from the Oeliassers.

St. 361 lies at the same spot as the earlier St. Ca 3. According to Harting (67) sample Ca 3 con-

sisted of Radiolarian Ooze, while sample 361 of the Snellius expedition contains only 1—2% Radiolaria. It is probably to be ascribed to the inefficient method of sampling at that time, namely by attachment to fat, that it seemed as if Radiolarian Ooze had been deposited at St. Ca 3.

Samples 231, 232, 233, 234 and 361 contain, moreover, brown or sometimes green porous volcanic glass, in sample 233 it is even more common than colourless glass. Similar brown volcanic glass was found in sediment 358, so that it seems to be connected with eruptions of the Banda Api.

The various components of samples 231, 232 and 233 are reflected in the composition of the rock particles of these sediments. Those of 233 consist partly of green augite with plagioclase and some highly pleochroitic hypersthene in brown and greenish volcanic glass (from the Banda Api), partly of faintly pleochroitic rhombic pyroxene with plagioclase and little colourless augite in colourless glass (andesite fragments from Ambon), in 232 there are, moreover, a few particles of mica-schists. In 231 the rock particles consist of mica-schist fragments and of bronzite and plagioclase-bearing colourless glass (from Ambon).

At St. 234 very little material was raised. It proved to consist chiefly of clay particles with some fine-grained minerals, lime particles (50-5 μ), Sponge spicules, Radiolaria and Diatoms. A few Globigerina fragments could be shown in these, together with plagioclase, quartz, muscovite, brown glass, bronzite in colourless glass, and augite. The material seems, therefore, to correspond to that of 232 and 233.

As we have already said, the mean grain-size in sediments 231, 232, 233 and 234 diminishes southwards. There is a striking resemblance between the mechanical diagram of samples 232 and 361, while on the other hand sample 358 lying more to the east and about equally far from the coast as 232 and 361 is more coarse-grained. This is probably due to the effect of currents at St. 358, as sediment 358 is also somewhat coarser than 360 lying close to the coast, while at the neighbouring St. 357 strong currents were observed („hard bottom").

The mineralogical composition of samples 360 and 358 resemble one another in a high content of muscovite, some containing many carbon particles, in the presence of anatase and in both containing fragments of mica-schists, in which garnet could sometimes be demonstrated. Sediment 358, however, is composed of various kinds of rock; while sample 360 consists chiefly of biotite and muscovite-bearing mica-schists, in which green and blue tourmaline is the principle heavy mineral, besides these usually pink garnet, zircon and traces of titanite and anatase occur. Sample 360 also contains mozaic-like quartz aggregates.

The material of sediment 360 might be derived from the southern part of Mid-Ceram, which Rutten (142) reports to be built up of crystalline schists.

Sediment 358 also consists largely of detritus of crystalline schists (with little tourmaline and more garnet than 360), probably derived from Mid-Ceram. Further it contains recent-volcanic material from the Banda Api, which includes pumice fragments, plagioclase, dark brown glass, a little dark green augite and some highly pleochroitic hypersthene (Verbeek bibl. 166). The content of this recent-volcanic material is comparatively small, the bulk of the gravel and the sand fractions 2—0,5 mm are composed of it, in fractions 0,2—0,1 mm it is little found and in the finer fractions it occurs only sporadically.

Both at St. 358 and St. 360 the rate of sedimentation seems to be rather rapid, as at neither of the stations clay casts are formed, while at St. 358, in spite of the frequent eruptions of the Banda Api, the terrigenous material greatly preponderates.

Sediment 358 contains further some minerals of terrigenous origin, such as actinolite, orthite, staurolite and chromite, which are not present in sediment 360, though they are in sample 322.

Sample 322 is a fine-grained sediment, which consists chiefly of clay (fig. 14) while the sand fractions contain moreover clay casts. The mineralogical composition greatly resembles sample 358, except that it contains no anatase and the debri of basic igneous rock shows principally old-volcanic habitus. The monoclinic pyroxene of 322 is seldom green, usually pale green or colourless, and a few titaniferous augites are pale brown-violet in colour; the rhombic pyroxene for a small part is strongly pleochroitic, the rest is faintly pleochroitic.

The islands lying in the neighbourhood of St. 322 have been described by Verbeek (168) and Wichmann (183) as containing cordierite-granite, quartzite and amphibolite on Manawoka; mica-schists and amphibolites on Watoebella; quartzite-schist, garnet-phyllite and greywacke-schist on

Kasiwoei and phyllite on Teor. Brouwer (22) found biotite and muscovite-containing mica-schists, muscovite-gneiss and quartzite on Teor. Of basic igneous rocks serpentine and garnet-containing gabbro is found on Manawoka, peridotite and serpentine on Teor (in the serpentine olivine, diallaag and chromite were sometimes found, while in others rhombic pyroxene and chromite were met with). On Kasiwoei radiolarite occurs; moreover on all islands limestone and coral rock is found.

The mineralogical composition of 322 corresponds in general to the composition of the rocks of the above mentioned islands, although no orthite, staurolite or titaniferous augite-containing rocks are found there. Titaniferous augite-bearing alkaline rocks and orthite-bearing granite and schists are, however, known from elsewhere (bibl. 142, 148) in the Boeroe-Timor arc, they therefore belong in this series.

St. 362 lies in the deepest part of the Weber deep, far removed from the larger islands. The mechanical composition of the sediment is of about the same type as 232 and 361; the latter samples were raised much nearer to the coast than 362. Until more samples from the deep part of the Weber deep have been examined it is difficult to understand how a sediment containing so comparatively little clay could be deposited in this basin, for in general it is the finest particles that sink into the deepest central part of the basin.

As the mineralogical composition in table 13 shows, the sediment consists chiefly of detritus of mica-schists, with perhaps material from other rocks, possibly of amphibolites. Concerning the origin of this material nothing can be said.

Finally the terrigenous portion of the Globigerina Ooze 364 is included in group I because muscovite predominates here. The mineral content of this sediment amounts to almost 1% of the whole sample, so that the inclusion of it in group I is certainly problematic. But the mineralogical composition and the mutual proportion of the minerals greatly resembles that of sediment 362. Sample 364, in contrast to 362, contains traces of green or pale-green augite and hypersthene, usually highly pleochroitic.

Concerning the origin of the material of 364 it may be remarked that little is known of the Tenimber islands, which lie to the south of St. 364 and are largely covered by coral reefs. Brouwer (21) found mesozoic rock cores on Jamdena, Laibobar and Mitak. He found crystalline schists on Mitak, they were amphibolitized and chloritized diorite-porphyry and a rock which may have been derived from a brecciated quartzite bank in crystalline schists.

On the island of Fadoh, lying to the north of St. 364, Brouwer (21) found large boulders of biotite-gneiss, biotite-muscovite-gneiss and amphibole-gneiss, which form the core of the island. The island is covered to a great extent by coral rock.

On the island of Koer, north west of Fadoh, Verbeek (168) found blocks of gneiss, mica-schist, quartz-schist and serpentine in ravines.

St. 364, with the above mentioned islands, lies on a ridge which borders directly on the Banda sea, and seems to be built up of older rocks. The composition of the rocks of the surrounding islands is not in contradiction with the inclusion of the terrigenous material of sediment 364 in group I. The introduction of terrigenous components at St. 364 is small as the sample consists for 90% of Foraminifera.

St. 363 lies on the same ridge at a depth of 950 m. At this station a Terrigenous Mud has formed which largely consists of clay (fig. 14a). The sediment further contains clay casts, usually broken Foraminifera particles including arenaceous Foraminifera particles, about 1% siliceous organisms (principally Radiolaria) and pyrite. In the clay casts and in the arenaceous Foraminifera pyrite sometimes occurs, with or without a limonite sheath. The mineral content of the sediment is very small, about 0,5% and contains plagioclase, orthoclase, quartz, glass, yellowish brown or green biotite and muscovite, while of heavy minerals there are only a few grains of epidote. This result from the mineralogical examination is too inadequate to justify the inclusion of the sediment in any of the five groups of Terrigenous Muds.

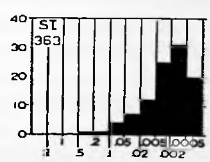


Fig. 14a. Mechanical Analysis of the Terrigenous Mud 363.

Above St. 363 there is apparently not sufficient supply of nourishment for a great development of Foraminifera and the formation of Globigerina Ooze on the bottom. It is not probable that here the rate of settling of the clay particles is so rapid that they would hinder the formation of Globigerina Ooze.

II. Terrigenous Muds, chiefly composed of detritus of acid igneous rocks and a small amount of material from crystalline schists

The mineralogical composition of this group is characterised by the predominance of acid plagioclase and quartz; mica, in contrast to group I, takes a subordinate place. Epidote and amphibole, partly accompanied by pyroxenes, form the principle heavy minerals; the content of tourmaline, garnet and zircon is lower in proportion to the total amount of heavy minerals than in group I.

These Terrigenous Muds occur in larger quantities in the north westerly Banda Sea (217, 216, 215, 214, 212, 331, 218, 209, 221 and 220) and in the Ceram Sea (228, 229 and 330) and moreover east of it at St. 89. They were further found near the north coast of West Flores at St. 182 and south of the Toekang-Besi islands in the Globigerina Ooze 201. Combined with material from group III they occur in and near the eastern Ceram sea (257, 355, 325, 354A), west of Babar (370), in the seas around Timor and near the northern arm of Celebes; combined with basic old-volcanic material material group II is present in sediment 145.

St. 182, near Flores' north coast, is only 5 km from the coast. The mechanical analysis of sample 182, given in fig. 15, shows that fine sand (100-20 μ) forms the chief component of the sediment.

Although the lime content of this sample amounts to 37.7% it must be regarded as a terrigenous deposit, as the total content of Foraminifera particles is not even 10%, while calcite and aggregates of microcrystalline calcite particles form an increasing contribution to the finer fractions, as may be observed in fraction 50-5 μ.

The mineralogical composition in table 14 indicates acid igneous rocks as parent material, while accompanying it is a considerable quantity of muscovite some of which include carbon particles, seeming to indicate a certain admixture of schist material. This composition corresponds only partially to the geologic structure of Flores.

Ehrat (49) found solid rock of porphyric granodiorites (and dacites) at various points of Flores, which he tentatively ascribes to a neogen intrusion phase. It has caused more or less metamorphosis locally of the existing formations, although no slates, schists or similar formations of old habitus have been attacked.

Before this Wichmann had found boulders of acid igneous rocks in a few widely separated river valleys, amongst others in the Reo-river which enters the sea some 20 km east of St. 182; they always occur, however, beside boulders of basic eruptive rocks.

Ehrat records local miocene sedimentary rock (Foraminifera limestone), chiefly covered by andesites, from the Wai Nggilat, flowing into the sea a little to the south west of St. 182. Basalts and dacites also occur, and various porphyric rocks viz dolerites and quartz-diorite-porphyres. In the Wai Welak, entering the sea to the south of St. 182, he found chiefly andesites, as well as a few exposures of miocene limestone and polymikt sandstone. A tributary of the Wai Welak rises in the more southern limestone formation.

Considering the composition of the neighbouring coast of Flores a mixture of detritus from chiefly basic eruptive rocks with detritus from acid eruptive rocks and of limestone might be expected. But basic eruptive rocks are practically absent in sample 182, while the acid eruptive rocks are very conspicuous and moreover it seems to contain material derived from schists.

As reported by van Riel (bibl. 130, fig. 19) the coast of Flores towards St. 182 slopes very gradually for the first 3 km, after which „the sea floor slopes abruptly at an angle of 33°"; St. 182 lies at a following, almost flat part.

A question arises as to whether at St. 182 it is possible that material of submarine landslides has collected, a question which cannot be decided on the authority of a solitary sample.

The sediments from this group in the north western Banda Sea, are fine-grained (fig. 15). Only at the coast near Taliaboe a „small" amount of sand was raised, owing to currents along the coast. Sediments 216 and 218 contain rather more fine sand of 50-20 μ than the other samples, which show either the typical mechanical diagram of Terrigenous deposits with a peak in fraction 20-5 μ or a peak in the 5-2 μ fraction owing to the high clay content. The two latter types in this part of the Banda Sea vary both in the horizontal and vertical direction (215—215A and 331A—331B—331C).

The mineralogical composition as seen in table 14, shows only small variations in these samples:

1. anatase occurs only in 216 and 215.

2. the chromite content diminishes from the south west (214) to the north east (216).

3. the content of faintly pleochroitic rhombic pyroxene which is often strongly lamellated and with ragged ends, is higher in 214 than in the other samples,

4. the augite in 214 is colourless or pale green, in the other samples there is also common, green augite, pale violet augite was only found in 331A and 212,

5. in the sand preparation treated with hydrochloric acid which forms sample 217, only epidote, zoisite, actinolite and garnet were found of the heavy minerals, although the mutual proportion of the light minerals corresponds to that of the rest of the samples.

The muscovite in these sediments is usually translucent, a small part is dusky from inclusions, very occasionally the muscovite includes rutile needles.

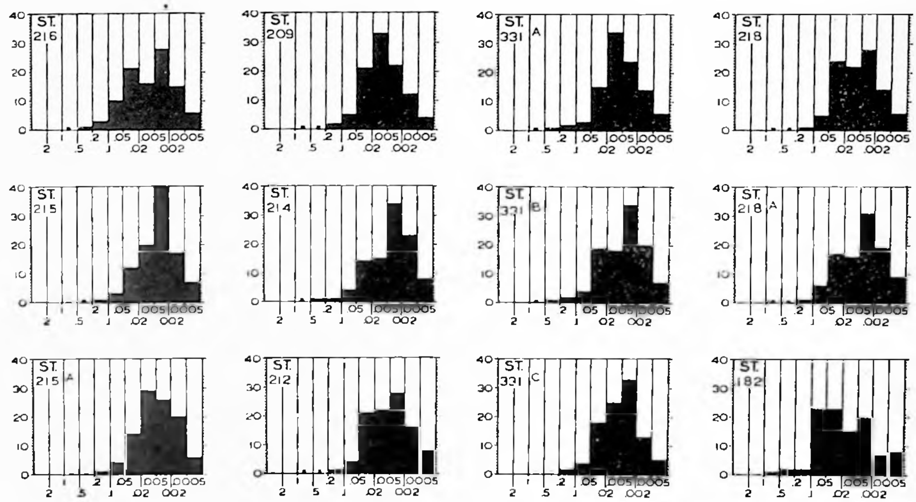


Fig. 15. Mechanical Analyses of Terrigenous Muds of Group II, N. of Flores and in the N.W. Banda Sea.

The principle components of these Terrigenous Muds, detritus of acid igneous rocks and to a less extent crystalline schists, are found frequently on the islands to the north of the N.W. Banda Sea.

According to the research by Brouwer (18), granites, granite porphyres, quartz porphyres etc. on the south side of the Soela islands, Taliaboe and Mangoli are widely distributed. Besides this diorites and diabases, granite-aplite, granite pegmatite, minette, spessartite, liparitic dacite and andesite, including titaniferous augite-containing rocks, are described by Brouwer. The most frequent heavy minerals in these rocks are amphibole, epidote and garnet. Crystalline schists occur in western Taliaboe and in middle and east Mangoli; they predominate on the island of Soela Besi over the acid igneous rocks; they are both metamorphic sediments principally phyllites, mica-schists and quartzites and metamorphic eruptive rocks: gneiss, amphibolites, amphibole-schists and epidote-chlorite-schists.

Of the detritus from limestone and marls, which are also widely distributed on the Soela islands, hardly any signs are found in the sediments of the deep Banda Sea.

The steep west coast of Boeroe (bibl. 174) almost entirely built up of limestone, can have contributed little to the sediments, considering their low lime content. The transport of material from the small hilly islands and isthmuses lying before this mountain range and consisting of conglomerates of crystalline schists with a little hornstone and limestone, can be only limited.

The islands of the Banggai-Archipelago, as reported by Verbeek (168), consist of a core of old schists with granite rocks and crystalline limestone, on Bangkoeroeng he moreover found diabase. Further young coral rock and sandstones were found. Koolhoven (89) instituted a more extensive examination of the islands of Peling and Bangkoeroeng. They proved for the most part to consist

TABLE 14. Mineralogical Composition of Terrigenous Muds

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	olivine	green and brown hornblende	red hornblende	tremolite	actinolite	biotite	muscovite	chlorite	apatite	epidote and zoisite	staurolite	zircon	tourmaline	garnet	titanite
182	2																								
	3		0,5																						
	4		1	4		5										0,5	10	1							
	5		1	30	2	20			0,1			tr.			0,1	0,2	25	1		tr.		tr.	0,1	tr.	
	6																								
216	2																								
	3		tr.	tr.	tr.	tr.										tr.									
	4		1,7	1	0,3	0,5		0,5								0,5	0,2								
	5		3	12	1	6		0,5	0,4	0,1		0,3		tr.	0,4	1	5	0,5	tr.	0,4		0,2	0,2	0,2	tr.
	6																								
215	2																								
	3		0,2																						
	4		0,3	tr.								0,1				0,2	0,3								
	5							same as in 216																	
	6																								
215A	2															36									
	3																								
	4	0,1	0,2						tr.	tr.					tr.	2	tr.								
	5							same as in 216																	
	6																								
214	2																								
	3			0,1												0,1	tr.								
	4		0,1	tr.		tr.		tr.								0,1	0,1	tr.							
	5	1	4	15	1	7		3	0,4	0,6		0,2		0,1	0,5	0,5	6	2	tr.	0,5		0,2	tr.	0,2	tr.
	6																								
212	2	0,5																							
	3		0,2																						
	4		0,5	0,3		0,1		0,3								0,3	0,3								
	5	1	6	30	1	14		8,5	0,5	0,1		0,4		0,1	0,3	0,5	9	0,5	tr.	0,6		tr.	0,3	0,3	tr.
	6																								
331A	2																								
	3			0,2		0,1		0,1																	
	4																								
	5							same as in 212																	
	6																								
331B	2																								
	3																								
	4		tr.	tr.												tr.	1								
	5							same as in 212																	
	6																								
331C	2																								
	3																								
	4	0,3	0,2	0,1				0,1				0,1					0,2								
	5							same as in 212																	
	6																								
218	2																								
	3	0,5																							
	4	1	0,5	0,4	tr.	0,1		1,5	tr.	tr.						1	2								
	5							same as in 212																	
	6																								
218A	2																								
	3		0,1													0,1	0,3								
	4		1	0,8		0,2				0,1	tr.	tr.	tr.	tr.		1	4								
	5							same as in 212																	
	6																								
209	2																								
	3																								
	4			0,1				2									0,1								
	5	5	3	5		0,5		28	0,1			0,1			0,1	tr.	3	0,5		0,1		tr.	tr.	tr.	
	6																								
229	2															1									
	3			0,5		0,5																			
	4		0,2	3	0,3	2		0,5				0,2				2	6			tr.				tr.	
	5		1	25	0,3	17		0,5	0,1	0,5		0,5	0,1	0,5	2	2	20	0,5		2		0,2	0,2	0,5	0,1
	6																								

belonging to Group II.

rutile and brookite	anatase	chromite and picotite	magnetite and ilmenite	pyrite	zeolites	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Coccoliths	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
			0,3	tr.			5 3,5		5,5 25 80 80	80 88 72 12	20 5 2	1 0,5	tr.	0,1	0,1 1	0,5 3,9	3	100 94 75 19 19,8	0,5 tr. 1 0,2			0,5 tr. 1 0,2		0,6 1,6 1,8 23,0 23,1
tr.	tr.	tr.	0,8	0,2			1 0,3	2 7 4 5	2 12,7 36,4 50,5	100 87 76 50	1 1 1	0,3 0,3				1		100 88 77,3 52,3 37	10 6 10 11	tr. 4 1 1	tr.	10 10 11 12	0,3 0,5	0,4 1,3 2,7 9,7 20,8
							0,5	94 92 82 30 20	94 92,2 83 88,5 84	4 7,3 4 6						1		4 7,3 4 7 5	1 3 7	0,5 12 1 3,3	0,2	0,5 13 4 10,5	2 0,5 0,5	0,1 0,4 0,6 3,5 12,2
				0,5			0,3 0,1	32 60 74 32 14	68 60 76,7 73,7 82,5	32 39,5 19 20 10	0,5 0,5	tr.						32 40 19,5 20 10	0,5 4 4	tr. 3 2 3	0,2	tr. 3,5 6 7,2	0,3 0,3 0,3	0,2 0,1 1,1 3,8 13,6
tr.		0,3	0,5	tr. 0,1			0,5 0,5 0,5	4 6 9 8 5	4 6,7 10 51,7 61,2	94 91 79 43,5	2 0,3 0,7 0,5							96 91,3 79,7 44 32	1 2 3 4	0,5 8 1 2	0,3	1,5 10 4 6,3	0,5 0,3 0,3 0,3	0,15 0,6 1,3 4,1 14,2
tr.		tr.	0,3				0,5 0,5	99 95 86 18 7	99,5 95,2 88,3 92 90,8	0,5 1 1 1							3	0,5 1 1 4 2	0,8 0,5 1,8 3	3 10 2 3	1	3,8 10,5 3,8 7	0,2 0,2 0,2	0,2 0,5 1,2 3,7 21,2
				tr. 0,1			0,1 0,5 2	98 96 88,5 20 12	98 96,5 89 97 90,5	1 1,5 0,5 0,1	1 0,3					0,9		1 2,5 0,8 1 1	1 1 5	1 10 0,5 2,8	0,2	1 1 10 1,5 8	0,2 0,5 0,5	0,16 0,6 1,8 3,2 15,3
				tr. 0,5			0,5	99 96 88 28 20	99 96 89 94,5 89,5	3 2 2								3 2 2 2	1 0,1 0,2 1 4	0,9 8,8 2 4	0,2	1 1 9 3 8,2	0,5 0,3	0,3 0,5 1,5 4,1 18,7
				tr. 3			0,2	96 80 78 44 13	96 80 79 74,2 58,5	4 12 12 20	tr. tr. tr.	0,1 0,3					1,2	4 12 12,1 21,5 2	1,6 3 2	8 7 1 37	0,2	8 8,6 4 39,2	0,3 0,3 0,3	0,3 0,3 2,0 4,2 17,7
					tr.		1 2	99 89 74 16 8	99 89,5 81,5 94,2 88	2 0,4 0,5	4 2				0,5	0,1 0,5		6 2,5 1,5 0,5	0,5 1 2 7,5	4 15 2 2,5	1	4,5 16 4 11	1 0,3 0,5	0,14 0,2 1,0 5,0 23,7
				0,2 1	tr. tr.		0,3 0,5 0,3	10 22 7 8	10,5 29,5 75,7 76	† 82 61 20	† 1,5 0,7 tr.	tr. 0,5			0,5	0,5	†	83,5 62,2 21 16	2 2 2 5	3 6 1 3	tr.	5 8 3 8	1 0,3 0,3 tr.	0,03 0,4 0,8 5,9 17,4
			tr.				2 tr. tr.	100 98 88 48 15	100 100 90,2 93,5 90	0,5 2		0,1					0,2	0,8 2 2	tr. 4	9 4 3	0,5	9 4 7,5	0,5 0,5	0,3 0,5 2,0 5,0 21,2
tr.			1	2 3				99 91 71 15 3	100 92 85,3 91 90	1 0,7 2						2		1 0,7 4 1	1 2 3 5	5 11 1 2	tr. 1	6 13 4 8	1 1 1 1	0,3 1,2 0,8 6,0 15,0

Table 14. Mineralogical Composition of Terrigenous Muds

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	olivine	green and brown hornblende	red hornblende	tremolite	actinolite	biotite	muscovite	chlorite	apatite	epidote and zoisite	staurolite	zircon	tourmaline	garnet	titanite
330A	2																								
	3																								
	4				tr.	tr.										0,5	1	1							
	5		same as in 229																						
	6																								
330B	2																								
	3		0,5																						
	4		0,2	0,2		0,2		0,2							0,2	0,5	0,2								
	5		same as in 229																						
	6																								
330C	2																								
	3																								
	4			0,2		0,2									0,1	1	0,5								
	5		same as in 229																						
	6																								
228	2	3		1		5																			
	3	1		1		0,5																			
	4			2		tr.											tr.	tr.		tr.					
	5		0,3	12	0,3	7		tr.	tr.						tr.	0,3	7	1		tr.		tr.	tr.	tr.	
	6																								
217	P		†	†		†									†	†	†	†		†				†	
220	S	†		†	†	†			tr. (12)	tr. (3)		tr. (8)			tr. (18)		†	†		tr. (23)		tr. (6)	tr. (8)	tr. (20)	tr. (1
221	P	†		†		†	†					†			†	†	†	†		†			†	†	
201	5		3,5	1		1		12	0,1 (19)	0,1 (20)		0,1 (14)	tr. (1)	tr. (1)	tr. (9)		0,3			0,1 (13)	tr. (2)	tr. (3)	tr. (2)	tr. (7)	tr. (1)
89	1																								
	2																								
	3																								
	4		tr.	tr.		tr.																			
	5		1	2	tr.	2		0,3	tr. (24)	tr. (27)		tr. (33)	tr. (2)		tr. (2)	tr.	0,5	tr.		tr. (2)		tr. (2)		tr. (7)	
	6																								
145	3			3		0,5		1								0,5	0,5	0,5							
	4		1	4		0,5		12								1	2								
	5	3	7	27		4		13	1	1		0,5			0,5	3	8	1	0,2	1		0,1	0,1	0,5	tr.
	6																								

of limestone, from which terrigenous material was completely absent, and of few quaternary coral rock. Granodioritic rocks were found much on Bangkoeroeng and little on Peling; they are partially hydrothermally altered. Crystalline schists are found in west and middle Peling, they were especially muscovite-gneiss and also mica-schists, amphibolites, biotite-actinolite-schists, quartzite etc. Around the older rocks on Peling are found limestones, marls and sandstones, which contain chiefly decomposition products from a schist-granite-area.

As the limestone areas are practically unwatered, only the material of crystalline schists, acid intrusion rocks, sandstone and marls will be carried away from these islands.

In the eastern areas of the S.E. arm and the East arm of Celebes, in contrast to the Soela islands and the Banggai Archipelago, there are only small occurrencies of crystalline schists (phyllites, garnet-mica-schists, quartzite-amphibolites and actinolite-schists) while acid eruptive rocks are nowhere found as solid rock (Brouwer (25), von Lòczy (101). In the northern half of the S.E. arm and in the southern part of the eastern arm, large masses of peridotite occur beside mesozoic sediments, which are composed of radiolarian hornstones, limestones, lime- and clay-slates and occasionally of sandstone, as the researches of Abendanon (1), Dieckmann and Julius (42) and Koolhoven (89) have demonstrated. North of this area, in the East-arm spreads the „Celebes-molasse"; Koolhoven records that here the upper series, consisting of conglomerates and sandstone, contains chiefly decomposition products of basic eruptive rocks and limestone, sometimes also of schists and granite.

belonging to Group II.

rutile and brookite	anatase	chromite and picotite	magnetite and ilmenite	pyrite	zeolites	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
								100	100															0,2
							0,7	95	95,7	0,3								0,3	1	2		3	1	1,0
							2	82	86,5	0,5								0,5	2	9		11	2	1,2
				0,3			1	11	95,5	0,5		tr.				0,5		1	2	1		3	0,5	4,5
				0,1				6	86									2	8	2,5	0,5	11	1	15,1
								100	100															0,1
							2	89	91,5	6								6	0,5	1		1,5	1	0,1
							2	82	85,7	3							0,3	3,3	1	7		8	3	0,5
				1			1	8	86	6,5						0,5		7	4	2		6	1	3,3
				4				5	85									6	5	2,5	0,5	8	1	16,0
							3	95	98		1						1	2						0,3
				2			3	93	98	0,4		0,1						0,5		0,5		0,5	1	0,7
				3			3	78	86	2								2	2	8		10	2	1,2
				5			1	6	92	0,7					0,3			1	5	1		6	1	4,4
				6				6	84						0,3			2	9	3	1	13	1	15,8
								2	11	30	58						1	89	tr.			tr.		0,4
								8	10,5	62	22					2	3,3	89,3	0,1	0,1		0,2		0,9
							8	10	20	63	4,5					1	0,5	69	9	2		11		1,3
tr.			tr.				5	2	35	41	0,3	tr.			1	6	12,7	61	4	tr.	tr.	4		9,5
				tr.			2	3	27					0,5	1			64	8	1	tr.	9		11,9
																†			†		†			
tr. (1)																								
		tr. (8)	tr.	1			tr.	2	21,5	—69,5—		0,5						70	7	1	tr.	8	0,5	4,0
																							†	0,04
								70	70	27	tr.							27					3	0,2
								68	68	—28—								28		1		1	3	0,8
								66	66	—30—								30	0,5	2,5		3	1	1,2
tr. (1)			tr.	0,3		tr.	tr.	49	55,2	—39,8—		tr.						39,8	2	2		4	1	1,8
				0,3				12	72,7									22	2	2	0,3	4,3	1	10,3
			2				1,5	63	72,5	0,5								0,5		27		27		0,3
			0,5				4	42	67	tr.								tr.		33		33		0,2
			1		tr.		1	20	93	0,5						0,5		1	1,5	4		5,5	0,5	3,1
								5	92							1,5		1,5	2	4	0,5	6,5		13,3

It would appear, therefore, that the sediments of the N.W. Banda sea consist chiefly of erosion products from the Soela islands, possibly mixed with material from the Banggai Archipelago. Erosion products from Celebes, considering the low content of basic eruptive rocks, have contributed little to these sediments. The higher content of enstatite-bronzite and chromite in sediment 214, which lies nearest to Celebes, compared to the other samples from the northwestern Banda-sea, corresponds to the supply of detritus of ultrabasic rock from the Celebes side.

Sediment 209, lying far south, contains in the sand fractions above 50 μ somewhat more basic volcanic material than the other sediments of the N.W. Banda sea; this material consists chiefly of green and brown volcanic glass, in which isotropic globules with a lower refractive index than the glass occur. The rock particles in this sample are composed of dark glass, containing many elongated augite laths with oblique ends: the laths also occur crossed or grouped in radiating clusters in the glass. The augite has an extinction angle of 40°—45°.

The same kinds of volcanic glass are found in diminishing quantities in samples 212, 331A, 218 and 214. They occur thus in the layers of 0—30 cm and are absent from the deep layers in these sediments, while in samples 216 and 217 they do not occur at all.

This recent-volcanic material is not entirely comparable in that of the Banda Api, the Gg. Api North of Wetar or of the Batoe Tara. It suggests that in the vicinity of St. 209 a submarine volcano may exist, of otherwise small activity, which may have supplied this material. In none of the samples

does the admixture of volcanic material amount to 5%, so that the sediments are all classified with th Terrigenous Muds.

The Globigerina Ooze 201, lying near the Toekang Besi islands, contains terrigenous material of which the composition resembles that of St. 214, although the mineral content of the sand fractions in 201 is low and it contains relatively more old-volcanic material than 214. Old-volcanic material forms the chief component of the small amount of terrigenous admixture in the Coral Mud 206.

St. 221 lies in the deepest part of the sill between the N.W. Banda sea and the Boeroe sea. St. 220 lies north of St. 221 on the submarine slope towards Soela Besi. At both stations small samples were raised, which consist principally of much decomposed, unrecognisable rock particles, acid plagioclase, quartz, and less muscovite. Sample 221 is distinguished from the other sediments in group II by the absence of basic old-volcanic material and of pyroxenes, and by a remarkable quantity of chalcedonised radiolaria, in which sometimes the shapes can be clearly distinguished. Sample 220 contains pale green augite, violet-brown titaniferous augite and faintly pleochroitic rhombic pyroxene.

The part of N.W. Boeroe by which St. 221 lies, as far as I know, has never been examined. Deninger (174), in N.W. Boeroe to the west of the Wai Tina and close to the shore, found Trias sandstone, brown hornstones and lumps of limestone; in the valley of the Wai Ruba he also found breccia of greenish black lime-bearing eruptive rocks. Boehm, Hinde (168) and Wichmann (183) found radiolaria in hornstone collected in the basin of the Wai Sasifoe lying to the east, which were partially altered in consequence of the hornstone being displaced by calcite. In this valley, moreover, the same conglomerates occur as on the west coast, with a few basic eruptive rocks.

Sediments 221 and 220 seem to be to some extent at any rate, composed of similar material, although in 221 the basic eruptive rocks are absent and in 220 the radiolarites do not occur, while the lime elements seem to have been largely dissolved during the settling process. The material of these sediments, especially of 220, may also have been derived partially from other islands, such as Soela Besi.

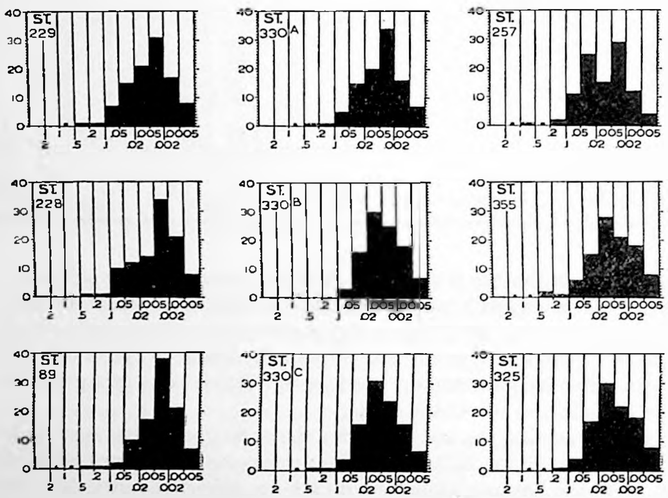


Fig. 16. Mechanical Analyses of Terrigenous Muds of Group II, in the Boeroe trough and the Ceram Sea.

The Terrigenous sediments in the Boeroe basin and samples 325 and 89 in the Ceram sea are of the same kind of mechanical composition as the deposits in the N.W. Banda sea (fig. 16). They are also fine-grained sediments, which have a peak either in fraction 20-5 μ or in 5-2 μ. At St. 330 the top layer contains rather more clay than the deeper sampled layers; as described this sediment consists of a number of different, not sharply defined layers. Only sediment 257, taken south of Obi Major, has a high fraction 50-20 μ.

The mineralogical composition of 228, 229 and 330 corresponds in general to the sediments of the N.W. Banda sea. The content of basic eruptive rocks in these samples is even lower than in the N.W. Banda sea, and chromite is absent in the samples in the Boeroe sea. On the other hand in 229 and 330 the content of actinolite and epidote is higher, so that these samples form a transition to the more easterly sediments. The three sampled layers of 330, 0—6 cm, 100—106 cm and 146—152 cm, respectively, show no difference in mineralogical composition worth mentioning (table 14). The content of detritus from limestone is highest in the least deep sediment 228.

The material of the sediments of the Boeroe sea is well represented on the islands which surround the sea. The acid igneous rocks and crystalline schists of Mangoli and Soela Besi have been already mentioned in the treatment of the similar sediments of the N.W. Banda sea. On north Boeroe crystalline schists, especially mica-schists, quartz-schists and amphibole-schists, in a less degree gneiss and phyllites, are widely spread, according to the researches of Martin (105). Rutten (136) and Hotz and also Rittmann (132) record crystalline schists, predominantly mica-schists, as occurring on the islands of Manipa and Kellang, the peninsular of Hoeamoal, and in small areas of N.W. Ceram. The northwest of Ceram, however, according to Rutten is principally formed of Trias-sandstone and conglomerates, in which limestone and hornstone occur with clay slate. These formations, together with the raised coral rocks and conglomerates which form the coastal district, probably yield the material which reaches the sea. Wichmann (183) describes boulders from the Wai Kama, derived from raised conglomerates, as granite, quartzite, radiolarite and especially „grauwacken". This Trias formation is also found on the islands of Boano and Kellang and on the north coast of Hoeamoal. Basic igneous rocks partly accompanied by intrusions of acid igneous rocks are also recorded from Kellang and Manipa.

On the Obi islands the researches of Wanner (173), Brouwer (23) and others have shown that basic and ultrabasic eruptive rocks are widely distributed. It must be concluded from the fact that detritus of basic igneous rocks is very sparsely represented in sediments 228, 229 and 330, that material from the Obi islands has contributed little to these sediments.

It is evident that the distribution of material from the Obi islands is not great in a southerly direction; in sediment 257, however, an admixture of material of basic rock, partially metamorphosed, is present (group III), as is shown both by the relatively high content of amphibole and the much higher content of chlorite and serpentine, as well as the presence of chromite. Quantitatively the admixture is not great, but still this sample is included in the mixed sediments, i.e. group II + III to distinguish it from the sediments containing very little or only a trace (228) of detritus from the Obi islands.

The fine sediment 89 is placed in group II; it contains very little minerals and differs from the terrigenous admixture in the Globigerina Ooze 87 near the coast of Ceram, by its higher content of muscovite and garnet, by the small content of zircon and by containing basic plagioclase with relatively much pale green augite and highly pleochroitic hypersthene.

The origin of the material in sediment 89 is not clear, it may be erosion products of the Trias-sandstone formation, brought down by rivers, which Brouwer (14) describes from the Nief area, consisting of much quartz and felspar with plagioclase, partly considerably basic, sometimes numerous muscovite flakes and little biotite and chlorite.

The last sample included in table 14, 145, will be discussed in the treatment of deposits in the Indian Ocean (group V).

III. Terrigenous Muds, principally detritus of intermediate to basic metamorphic rocks, sometimes mixed with older basic eruptive rocks

a. This group is characterised by the high actinolite content of the heavy minerals. It varies considerably in composition according to whether old-volcanic basic material or small quantities of acid eruptive rock or schisteous material contributes to the sediment. The most typical representative of this group is sample 369.

b. In the other group epidote predominates amongst the heavy minerals.

In connection with the sediments of group II the mixed sediments containing material from group II, 257, 355, 325 and 354A will first be treated. The mechanical composition of the terrigenous sediments (fig. 16) corresponds to that of the Terrigenous Muds of group II, 257 only contains somewhat more fine sand, with a diameter of 50-20 μ.

The mineralogical composition in table 17 shows that sediment 355 contains the greatest amount of detritus of basic and ultrabasic rock, while in sample 325 detritus of acid igneous rock predominates. The terrigenous admixture in the Globigerina Ooze 354A may be compared to the material in sample 355; the principle constituents are plagioclase, quartz and chlorite, the muscovite

content is slight, as is the content of amphibole, limestone detritus is especially represented in the fine fractions.

The terrigenous components of 355 and 354A are probably derived chiefly from detritus of the island of Obi Major, those of sample 257 are to a less extent also due to the same source. Besides the above mentioned basic and ultrabasic eruptive rocks there are acid igneous rocks on this island, while a few quartzites and mica-schists, occasionally an amphibolite, siliceous slates, sandstone-containing effusive material, and limestones are met with.

In sediment 325 there is only a small admixture of detritus of ultrabasic rock, as is shown by the presence of serpentine, chlorite and chromite in this sample. The comparatively high content of actinolite and epidote seems to indicate the possible presence of detritus of actinolite- and epidote-schists.

Sediment 325 is not properly defined by the classification in group II + a little of group III, it probably forms a transition to group IV as well, to which sediment 87, amongst others belongs.

Not much can be said about the origin of the material of this sediment. In the neighbouring part of North Middle Ceram Rutten (136) reports that Trias sandstone and clay slate with marine sands and conglomerates and Globigerina marls are the most common; crystalline schists, especially mica-schists and gneiss (Isal mountains) occur in subordinate quantities. In several river basins blocks of limestone were found. Basic igneous rock is rare, small blocks of serpentine were found in the bed of the Toloearang amongst other things.

The sediments west of the Obi islands, in the Lifamatola straits, the Batjan basin and north of the Soela islands, 225, 227, 80, 333, 334 and 335 in their terrigenous components belong to group IIIa.

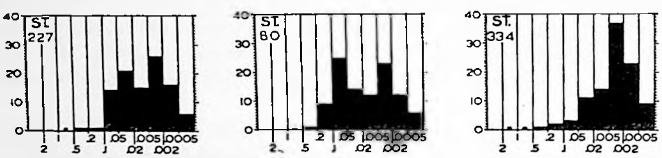


Fig. 17. Mechanical Analyses of Terrigenous Muds of Group III*a*, in the Molukken Sea.

The mechanical diagrams of the Terrigenous Muds in fig. 17 show that sample 80 contains fine sand with a chief fraction of 100—50 μ, that the sand in sample 227 is finer with a peak fraction 50—20 μ, while 334 consists chiefly of clay particles. Sample 333 (fig. 11) mixed with volcanic material and the Globigerina Ooze 335 also contain much clay.

The mineralogical composition of these samples in table 15 shows that sediment 80 contains the greatest amount of rock particles, in which chlorite-schists and mica-schists can be distinguished. In 335 and 334 and partially in 333 the grit is formed by andesite particles. The chlorite and serpentine content of samples 80 and 227 is relatively high; chlorite flakes, sometimes greatly altered, which are bluish green in a fresh condition, and fibrous serpentine may be plainly seen. The pyroxenes in samples 80, 227, 225, 334 and 333 are greatly affected, the augite is colourless or pale green, the rhombic pyroxene is colourless or faintly pleochroitic. In sediment 335, containing also recent volcanic material, common green augite and highly pleochroitic hypersthene occurs; they are found sporadically in 333, 334 and 80.

The terrigenous components of these sediments must have been brought chiefly from the east, especially from Batjan and the Obi islands. As has been said, on Obi Major basic and ultrabasic igneous rocks (diabase, gabbro, peridotite and serpentine) predominate, with moreover a good deal of andesites and few granitic and dioritic rock with very few crystalline schists.

During the Snellius-expedition Kuenen visited the islands of Obi Latoe and Poeloe Toesa, situated at the northwest corner of Obi Major. He describes (not yet published) ultrabasic and basic igneous rocks of these islands, namely peridotites, gabbro-diorites and less doleritic-basalts. In his opinion the gabbro-diorites form the principle constituents of the islands. In a smaller degree intermediate tuffs and pelitic rocks were found.

From the researches of Verbeek (168) and Brouwer (20) it is known that the high middle part of Batjan, the Sibella mountains, is composed of various older schists and igneous rocks; diorites, gabbros, peridotites and serpentines, andesites and basalts, gneiss, mica-schists (including garnet-staurolite-mica-schists), epidote-chlorite-schists and amphibolites (a.o. actinolite-schists) have been found. North and south of the Sibella mountains extinct volcanoes are found. The neogene in

north Batjan is composed of marls, Lepidocyclina-limestones, tuffs and tuffsandstones. On the lower, smaller islands of Mandioli and Kasiroeta, west of Batjan, Retgers (127) and Bücking (30) report andesites and diabase-porphyrite.

The composition of the terrigenous components of the above 6 samples bears the most resemblance to the rocks of the Sibella mountains of Batjan: the occurrence of staurolite in 80, 227 and 333 and the fact that sample 80 is more coarse-grained than 227 is explained by this derivation of the material.

Material derived from the Obi islands may also have taken part in the formation of the sediments. The occurrence of radiolarite, however, in 80 is not accounted for. The Soela islands, chiefly composed of acid igneous rocks and crystalline schists, can only have contributed a subordinate amount to these sediments, this applies also to the small sand sample 225.

There appear to be strong currents at St. 225, as in the whole of the Lifamatola straits, as at St. 223 a trace of sand and at stations 224 and 226 nothing at all was raised.

As has been said, in the sediments of the Ceram sea there is a certain amount of material belonging to group III. The terrigenous components of the Globigerina Ooze 328 belong principally to group III, and in a less degree to group II. The composition deviates, therefore from sediment 326, raised 10 km from the coast, while the terrigenous components of the Globigerina Ooze 327 stand between that of 326 and 328. The terrigenous part of sediment 328 would seem, therefore, not to be an erosion product from the north coast of Ceram. Sample 328 was raised in the deeper part of the Ceram sea, which, like the Flores sea, may contain material brought from elsewhere by currents.

Sediment 325 may also owe its material to a similar transportation.

Sediment 369, lying in the south west part of the Weber deep, has a very high amphibole and actinolite content. The actinolite shows both a prismatic and granular habitus. The hornblende is pleochroitic from yellowish green to greenish brown. The enstatite- or bronzite-augite, which is strongly lamellated, is pleochroitic from grey-green to yellow-green. The biotite is sometimes idiomorphic with green to brown colours. The sample contains much fine sand of 100—20 μ diameter.

The origin of the material of sediment 369 can only be partially sought on the islands of the Babar group. On the neighbouring island of Dai, belonging to the Babar group, Verbeek (168) found gabbro as old core while 15 coral reefs one above the other up to 600 m could be distinguished. In the gabbro there are dikes of granitite. Schistic hornblende-gabbro or amphibolite occurs as boulders. According to Weckerlin de Marez Oyens (see bibl. 104) the principle formations on the largest island, Babar, is a complex of sandstones and claystones alternating with diabases and diabase-tuffs; further quartz-porphyres, porphyrites and granites and a hill composed of serpentine were found. Now older basic eruptive rocks and a very little acid eruptive rocks form a part of sediment 369, although it chiefly consists of detritus of basic metamorphic rocks.

Here we may remark that on the more westerly islands Brouwer (12, 16) records various metamorphic sediments and basic igneous rocks, they compose the northern and central part of Leti and the island of Sermata. These sediments are principally metamorphic basic igneous rocks. The terrigenous components of sample 370, however, are much finer grained than those of sediment 369, much further off from Sermata, so that it is not probable that 369 consists of detritus from Sermata. Possibly sample 369 is partly composed of material precipitated from one of the islands of the Ceram-Timor arc, as on the small island of Mitak, belonging to the westerly Tenimber islands, Brouwer (21) found near mud wells a.o. amphibolitised diorite-porphyr and green tuff, and in the Globigerina Ooze 368 there is a small quantity of similar fine sandy material as appears in 369. In sample 368 moreover traces of titaniferous augite can be shown.

The Terrigenous Mud 364a, further north, has a somewhat higher mineral content than 368. The mineralogical composition of the three sampled layers 0—6 cm, 60—66 cm and 113—119 cm is practically identical. The upper layer has coarser sandy particles than the other two; these are chiefly rock particles in which muscovite-schist or phyllite, chlorite-schist, claystone, epidote-chlorite-schist and actinolite-schist occur. The quartz is both translucent and undulose extinguishing. Among the acid plagioclase albite occurs, partially altered into colourless mica.

Samples 370, 374, 375 and 376 raised along the northern coast of the islands stretching from

TABLE 15. Mineralogical Composition of Terrigenous

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green and brown hornblende	red hornblende	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite	apatite	epidote and zoisite	staurolite	kyanite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite
369	2																		6												
	3	2						3											0,5												
	4	6	6	2		0,2		8	0,2	0,2	0,3		0,5			1,5			2	2	0,5		0,1								
	5	8,3	15	9	tr.	6		5	1,5	0,5	1		4	0,3	tr.	14	tr.		0,5	1	0,5		1								
	6																														
364AI	1	95		3																2											
	2	90																													
	3	68		8		2										0,3				1	1,3		0,3								
	4	35		8		4		0,2	0,1	1		1	1			1			1	2	2		0,5	tr.				0,2			
	5	4		17		10		0,1	0,1	0,5			0,1			4			2	2	2	tr.	3	tr.		tr.		0,5	tr.		
	6																														
368	5		0,1	1	0,1	1		tr.	tr. (6)	tr. (16)			tr. (6)	tr. (1)		0,2 (45)			tr.	0,1	tr.		0,1 (21)			tr. (1)	tr. (3)	tr. (1)			
377	2	†																													
	3	33	tr.	15		4		1											tr.	1											
	4	32	1,2	10		4	0,1	4	0,7	tr.			0,5						2	4	2		tr.								
	5	25	3	18	0,5	10	tr.	2	1,2	1			1			6			2	4	2		3	0,2		tr.		0,1			
	6																										tr.				
161	S		†	†		†		†	†	†			†			†			†	†	†		†								
163	2																														
	3	†																													
	4	20	2	3		1		1											3	4	3										
	5	38	5	15		10		2	0,5	0,5			1			2			0,3	3	2	0,3	1			tr.	tr.	tr.	tr.		
	6																														
157	S	†		†		†		†		†						†			†	†	†		†					†			
158	2																														
	3	2	tr.	0,5		0,5		3	tr.	tr.			tr.						0,5	0,5	1		1		0,5	0,3	0,3	tr.	1	0,5	
	4	7	5	3		2		8	tr.	tr.			0,5						2	2	3										
	5	10	5	20		14		6	1	1			1,5		tr.	2,5	tr.		1	2	3		2		tr.		0,1	tr.	0,2		
	6																														
119	2																														
	3																														
	4	15	2	2		0,5		0,1	tr.	tr.										0,3											
	5	18	1	16		5		1	tr.	tr.			0,5		0,5	5			2	6	1	0,2	3			tr.	tr.				
	6																														
121	2																														
	3	2		0,2		0,2														tr.											
	4	1	0,5	0,3		0,3													0,1	1								tr.			
	5	0,5		4		1		0,5	tr.				tr.			0,5			tr.	7	0,8		0,5			tr.	tr.	tr.			tr.
	6																														
122	5		tr.	0,2		0,2		tr.	tr. (10)	tr. (6)			tr. (13)			tr. (29)			tr.	0,2			tr. (21)			tr. (4)	tr. (4)	tr. (2)	tr. (4)		tr. (2)
115	5		3	1,5		1,5		0,1	0,3 (15)	0,1 (6)			0,3 (17)	tr. (1)		0,6 (28)				0,5	0,2		0,5 (25)			tr. (1)		tr. (2)	tr. (3)		
188	5		1	2	0,1	1			0,5	1			1		tr.	1,2	0,2	tr.	tr.	0,3	0,2		0,6					0,1		tr.	0,2
43	2	1																													
	3		tr.										tr.																		
	4	1	tr.	2	tr.	tr.		1					0,5						3												
	5	4	6	6	0,5	2		1	0,2	0,2			1,5	0,1		0,5			1	tr.	0,5	0,3	0,3			tr.	tr.				tr.
	6																														
38	2							1																							
	3	tr.	tr.					1																							
	4	0,2	1	0,2				0,5	tr.	tr.			tr.						1												
	5	3	3	2	0,2	0,2		1	0,2	0,2			1	tr.		0,2			1	tr.		0,2	0,2			tr.					
	6																														
328	5		1	15	0,3	9		0,5	tr.	0,3			1	0,1	tr.	2	tr.		0,2	8	2		1			tr.	tr.	0,1	tr.		tr.
225	P	†	†	†		†		†		†						†			†	†	†		†								
227	2																														
	3			tr.				0,5													1										
	4		1	0,5		0,1		3								0,5			4	1	0,2										
	5	10	1	15		5		3	1	1			4	0,5	0,3	7				8	6	tr.	2	0,2		tr.	tr.	0,1			tr.
	6																														
80	2	†																													
	3	68	1					2												tr.	3										
	4	50	5	10	0,3	3		3		0,5			tr.			0,5				4	17										
	5	36	8	10	0,5	3	0,2	4	2	3			3	0,3	0,5	4		0,1	0,5	4	9		2	tr.				0,1		tr.	0,2
	6																														
333	5	6	8	8	0,2	3		20	1	2			1	0,2	tr.	3			1	2	2	tr.	1,5	0,2		0,1	0,1	0,3			
334	1							†																							
	2							2																							
	3							0,5																							
	4			tr.				1		tr.									0,1												
	5	4,5	7	1	0,2	0,3		8	0,2	0,2			0,3	tr.	tr.	0,4			0,3	0,1	0,2	tr.	0,2					tr.			
	6																														
335		7	8	0,5				29	0,5	1,5			05,			0,7			0,5		0,5	tr.	0,2				tr.				

Muds of Group IIIa.

magnetite and ilmenite	pyrite	zeolites	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Lamellibranches	Gastropods	Pteropods	Ostracode valves	Bryozoa	Alcyonarian spicules	calcareous Sponges	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
						10	16	84															84						0,06
						24	29,5	66	tr.														66	4	0,5		4,5		0,3
						28	57,5	30	tr.												1	2	33	2	7		9	0,5	2,2
1	0,3	tr.				7	76	15									0,5				3	4	22,5	0,5	0,5		1	0,5	17,0
	1					8	76																19,3	2	2	0,2	4,2	0,5	18,9
							100																						0,4
						7	97	80,5	2												0,5		3						0,5
	1			1	1	12	95,9	1	2												1		4		0,1		0,1		0,7
	3			0,3	6	22	88,3	3	2	0,2											2		7,2	0,3	4		4,3	0,2	0,8
tr.	20			0,1	5	19	89,5	4	1	0,2											1		6,2	2	2		4	0,3	1,6
	25				2	22	81																8	5	5	tr.	10	1	3,9
				0,1		7	9,8	--88----									tr.						88	1	1		2	0,2	5,7
								†	†																†				0,03
						2	56	--24----		1											7	8	40	tr.	1		1	3	0,4
						1	61,5	--20----		2											5	6	33	0,5	4		4,5	1	0,6
0,5					0,5	1	82	--12----									tr.				3	2	17	0,5	0,2		0,7	0,3	7,1
	tr.					1	87										tr.						12	0,5	0,1	0,1	0,7	0,3	23,4
†					†	†		†																					
								†																				†	0,03
								†																				†	0,06
						8	45	--30----		2											1		33	4	8		12	10	0,15
0,5						3	84,2	---3----													8	4	15	0,3			0,3	0,5	6,8
						2	84																14	1	0,5		1,5	0,5	27,4
								†	†		†	†	†		†						†								
								†	†																				0,02
2						3	16,7	--51----		1							1				0,3		53,3	4	16		20	10	0,3
						5	37,5	--35----					1								1	1,5	38,5	1	17		18	6	0,3
0,5						4	74	--12----												0,5	6,5	4	23	1	1		2	1	6,8
	3					1	76																21	1	0,5	0,5	2	1	18,5
	†							†	†	†																		†	0,1
	20						20	71	4	tr.				tr.								3	78					2	0,3
	18				0,5	0,2	38,6	58	2				0,2			0,2					0,5		60,9	0,3	0,2		0,5		0,3
0,3	2				1		62,5	24	1								0,5			tr.	10	1,3	36,8	0,3	0,1		0,4	0,3	4,2
	2					1	58										0,5	tr.	0,2	0,1			41	0,5	tr.		0,5	0,5	14,1
						40	40	59	1														60						0,2
						10	12,4	--87,6--															87,6						0,6
0,1					0,1	38	41,4	--55----													0,6		55,6	tr.	3		3		1,4
	0,5				0,5	19	35	--60----		0,2							0,2				0,3		60,7	2	2		4	0,3	2,0
	1					10	59										0,2		tr.	tr.			36,2	2	2	0,3	4,3	0,5	7,0
	1		tr. (5)		0,1	25	27	--70,5--		tr.							0,5						71	1	1		2		3,6
1	tr.		tr. (2)		0,5	24	34,3	--62,5--		tr.							0,2						62,7	1	1		2	1	2,9
				1	1	2	13,5	74,5	0,5	0,5			0,5			tr.	0,1					9,4	85,5	1			1	tr.	12,6
				3			4	95															95					1	0,3
				3		2	5	94	1														95						0,8
				2		5,5	15	--83,8--		tr.													83,8	0,2	1		1,2		1,6
0,5				0,5		9	34,3	--62----															62	3	0,2		3,2	0,5	4,3
	tr.					12	38																46	14	2	tr.	16	tr.	12,0
						85	86	12															12					2	0,2
						72	73	25	tr.														25	tr.	2		2	tr.	1,2
						71	74	--20,3--		0,2													20,5	0,5	4		4,5	1	0,9
tr.						52	64,5	--30,5		0,1							tr.						30,5	2	2		4	1	1,7
						24	56										tr.						30,5	8	4	0,5	12,5	1	6,6
0,2	3			0,3	tr.	8	52	44	0,2	0,4							0,3			tr.	0,1		45	2	0,5		2,5	0,5	11,8
						†															†				†				
								†		†														†					0,06
						3	4,5	80	0,1	0,4													80,5	7	6		13	2	0,8
						2	12,3	45	tr.	0,5												0,2	45,7	6	35		41	1	1,0
1						2	67,2	--25----									tr.					1,3	26,3	5	1		6	0,5	3.8
	tr.					3	63																28,5	6	2	0,3	8,3	0,2	21,5
								†																				†	0,1
							74	20															20	1	5		6		0,6
							93,3	2													0,7		2,7	1	3		4		8,6
1	1	0,5			0,5	0,5	94	2									tr.				2,5		4,5	0,5	0,5		1	0,5	25,2
	1					0,3	88																4	5	2	0,5	7,5	0,5	13,6
2	2				0,5	4	68,2	--29,5--															29,5	1	1	tr,	2	0,3	5,0
										†																			0,03
							2	95															95		2		2	1	0,3
						36	36,5	--60,3--															60,3		3		3	0,2	0,8
						38	39	--47----															47	1	13		14		1,5
0,3	1					14	38,3	--55----									tr.				0,5		55,5	3	3	tr.	6	0,2	2,5
					0,5	4	59,5																25	10	4	1	15	0,5	11,3
2						5	56	42	tr.														42	1	1		2	tr.	7,1

Babar to Timor are given on the map as group II + IIIb. Both acid and basic and even metamorphic rocks contributed to form these sediments.

The mineralogical composition in table 17 shows that epidote forms a high percentage of the heavy minerals. The rock particles of the samples are light red in colour and greatly weathered, so that they cannot be further defined; in 374, only, andesite particles are found. The quartz grains are translucent or dusty, more or less angular, fragments. The volcanic glass is colourless with only hair-like inclusions; in 374 and 376 there is moreover light brown recent-volcanic glass of a porous structure which may be derived from Damar, like the andesite particles in 374. The monoclinic pyroxene is pale green; in 376 and 374 titaniferous augite is found, in 375 moreover, common green augite occurs. The rhombic pyroxene is usually faintly to moderately pleochroitic, it is affected and sometimes shows ragged ends. Part of the muscovite contains carbon particles.

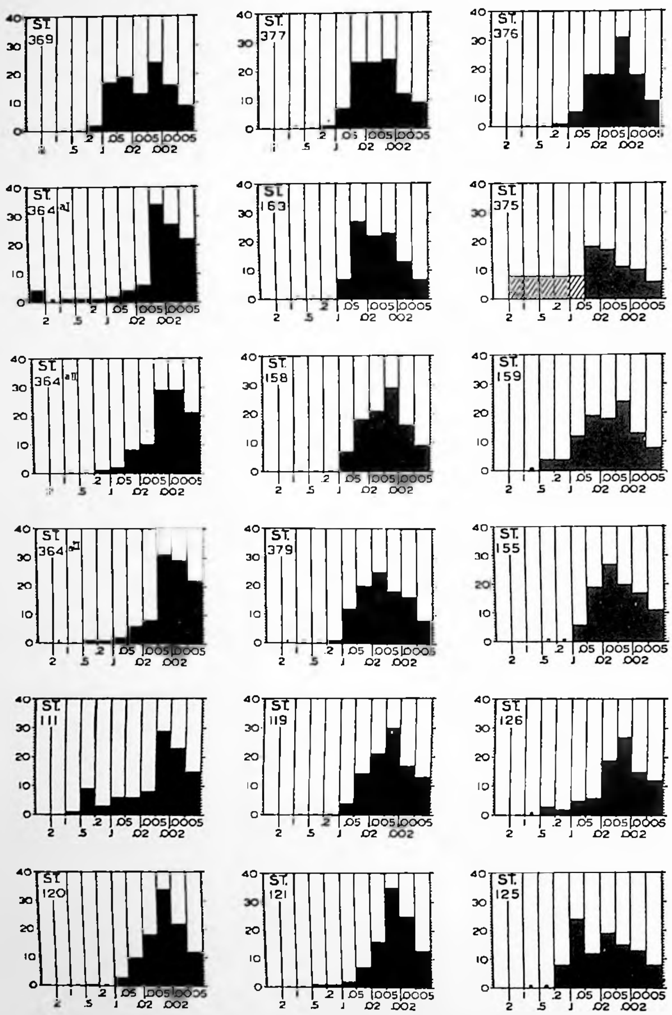


Fig. 18. Mechanical Analyses of Terrigenous Muds of Group III in the S.E. part of the Indian Archipelago.

The mineral content of the Globigerina Ooze 370 is low, while the epidote content in the minerals is relatively high. This renders it probable that these components are derived principally from Sermata, which lies to the south west of St. 370.

Verbeek (168) reports Sermata as consisting of old rock, partially covered by coral rock; he records schistic calcite-bearing diabase-tuff and phyllite. Brouwer (16) describes epidote-amphibolites, epidote-chlorite-schists, epidote-biotite-schists, epidote-containing quartzites and graphitoid-phyllite; these rocks occur in deeply folded strata in the valley of two small rivers which enter the sea on the north coast of Sermata by Mahleta and could therefore distribute their material in the direction of St. 370.

In the Terrigenous Muds 375 and 376 (fig. 18) the grain diameter of the minerals is usually less than 100 μ, as in the various sampled layers of the Globigerina Ooze 374 (fig. 26).

Sample 375 taken 20 km west of Leti, like 370, shows a high epidote percentage in the heavy minerals. The origin of this material is uncertain. No research has been published on the northern part of Portugese Timor. According to Molengraaff (112) the south west and south coasts of

Leti consist of continuous young coral-reef limestone, on the south east coast several small rivers run into the sea, which only carry off water for a few months of the year. These rivers rise principally in the central hilly country which is built up of metamorphic sediments and to the south gradually passes into little altered permian sediments (greywacke, sandstone, clay slate and some limestone). The metamorphic rocks are both altered sediments (phyllite, quartzite, mica-quartzite, lime-phyllite and limestone) and metamorphic igneous rocks (various amphibolites, including those from diabase and epidote-chlorite-schist).

It cannot be immediately assumed that material from Leti has formed sediment 375 as in that case a higher muscovite and chlorite content would be expected.

St. 374 lies particularly in the sphere of influence of northern Leti and of Kisar, St. 376 in that of Kisar, of East Wetar and of the N.E. point of Timor.

The rivers of northern Leti run principally through the above mentioned metamorphic sediments and the northern zone of the metamorphic basic igneous rocks, in which sometimes the original rocks (diabasic rocks) can be recognised. Brouwer (12) described from this region various kinds of schistic amphibolite, some with much chlorite, and further albite-amphibolite, epidote-chlorite-schist, chlorite-schist, amphibolitised diabase porphyrite, biotite-plagioclase-schist; of metamorphic sediments garnet-mica-schist and muscovite-biotite-gneiss occur, with others.

The island of Kisar is only 195 m high. Verbeek (168) describes it as a core of schisteous rock surrounded by a grey, dry wall of coral rock, only broken where the mouths of small rivers penetrate it.

Kuenen (not yet published) who visited Kisar during the Snellius-expedition, found that: „the bulk of the rampart is formed by schists, for there is only a thin coating of coral rock." He attributes the existence of the wall to the dry climate of the island, which gives greatest play to mechanical erosion and the soft and crumbly schists would disintegrate more rapidly than the compact coral rock. The schists covered by this coral rock thus formed a wall, behind which the unscreened country rock has been worn down to a considerably lower level.

In the interior Verbeek found principally amphibolites, with some quartzite. He also records, from Reinwardt's collection described by Wichmann, rocks from Kisar, viz. phyllite, siliceous schist breccia and mica-schists.

Kuenen found the same kind of rock on Kisar, namely only crystalline schists; he describes the occurrence of much mica-schists and gneisses, moreover, hornblende-schist, hornblende gneiss, sericite-quartzite and quartz-breccie. The rocks are almost all very fine-grained and friable; plagioclase, orthoclase, quartz, hornblende and biotite are frequent, muscovite is scarce, while sericite and chlorite are almost absent.

The fact that in sample 374A basic material is more conspicuous than in the three other samples here mentioned can be accounted for by the transport of terrigenous material to this sediment from North-Leti, a less amount may come from Kisar. The variation in the composition of these constituents is very small in the different layers of 374.

Concerning the origin of the Terrigenous Mud 376 it may be remarked that the composition is not in contradiction to the expectation that material from Kisar has contributed to it. A larger part of the sandy material of this sample corresponds to the composition of the rocks of the S.E. coast of Wetar. N.E. Timor has not been examined.

Heering (74) who examined East Wetar records that for the most part it consists of volcanic rocks of young-tertiary age, which show a submarine character. Lavas, sometimes with intercalated strata of Globigerina-limestones were found.

The volcanic rocks are divided into rhyolites, dacites, quartz-bearing keratophyres, andesites and keratophyres, basalts and doleritic basalts and spilitic rocks.

Moreover deep-seated rocks occur on the island.

Albitisation of the rocks in the areas where deep-seated rocks occur, he calls a remarkable phenomenon.

The greater part of the island is surrounded by a living reef, while the coasts are partly formed by upheaved coral rock terraces.

On the S.E. coast of Wetar two ample rivers discharge, the Meta Mapoen and the Meta Masapoen. In the valley of these rivers and along the S.E. coast chiefly dacites and andesites and their

albitised equivalents were found by Heering, amongst which rocks very rich in glass, breccias and tuffs, with obsidians occur. Subsidiary silicified dacite-breccia, basalts and doleritic rocks and Globigerina limestone were found, few spilitic rocks occur. Of the deep-seated rocks Heering found in the valley of the Meta Masapoen quartz-augite-diorite to quartz-gabbro.

In sediment 376 basic volcanic material is present in small quantities, the glass content of the sediment is low, dacitic material probably preponderates.

Sediment 247, north of East Wetar is also classified in group II + IIIb according to its mineralogical composition (see table 17). Little material was raised at this station. The sample contains a good deal of much weathered rock particles and much colourless glass, which contains fine needles and shows a similarity to that of St. 253^L by Ambon. Some light brown glass which included air bubbles is probably derived from the Gg. Api north of Wetar. The sample contains moreover a good deal of acid plagioclase and quartz with less basic plagioclase, chlorite and biotite. The content of heavy minerals is low, the most common are green augite, green hornblende and epidote. This small sample is thus principally composed of basic and intermediate eruptive rocks, combined with some material from highly altered volcanic rocks. Strictly speaking the sediment is not correctly defined by being classified in group II + IIIb; intermediate volcanic rocks which are partly rich in glass, and partly strongly altered are its chief components.

Heering (74) records from the N.E. side of Wetar the occurrence of glass-encrusted andesites, augite-andesites, dacites some rich in glass, rhyolites, quartz-diorites, dolerites and volcanic agglomerates and breccias.

Sediment 247 may be considered as detritus from N.E. Wetar, but there is no sign of rhyolites, as sanidine was not found in it; the presence of traces of rutile and anatase in this sample seems to indicate the presence of material brought from elsewhere. The chlorite in 247 as in 376 is secondary chlorite, originating on land by the weathering of andesites and dacites.

Round the island of Timor lie sediments which all belong to group IIIa, although in samples 125 and 126 there is moreover material from group II, while the small sample 162 (of table 20) contains basic volcanic material. This last sample consists of rather coarse material, covered by a film of manganese, of which hypersthene-andesite particles, basic plagioclase and volcanic glass (both colourless and massive and green-brown with air bubbles) form the principle constituents. Besides these some schisteous rock particles, small quantities of carbon-bearing muscovite and chlorite occur. Among the heavy minerals moderately pleochroitic hypersthene predominates. This material corresponds on the whole with that of the extinct pyroxene-andesite volcano of the island of Kambing. The island has been described by Verbeek (168). Strong currents seem to have carried away most of the finer terrigenous material which, as shown in table 15 and fig. 18, forms the sediments derived from Timor. Sediment 162, thus, belongs to group V.

The rest of the Terrigenous Muds along the north coast of Timor are very similar in their mineralogical composition (table 15). The mechanical composition of these samples in fig. 18 shows that 377, 163 and 158 are finer terrigenous deposits, which consist chiefly of material of 50—2 μ diameter. At St. 161 only a „trace" was raised; the material chiefly consisted of clay casts with less minerals and with few Foraminifera particles. The mineral composition corresponds to that of 377 and 163, although the coarser components are absent, such as rock particles. Sample 157, raised close to the coast, contains fairly coarse terrigenous material and shell sand, benthonic Foraminifera and less pelagic Foraminifera.

The rock particles in these samples are mostly greatly decomposed and undefinable. In 158 and 163 there are some subordinate andesite particles. Translucent sharp-edged quartz was found beside dusty quartz. The pyroxenes show signs of decomposition; the hornblende is partly fibrous. The undefined calcareous debri of these sediments is formed by microcrystalline calcite aggregates.

The geology of Timor is not sufficiently known to allow of a comparison of the composition of these sediments with that of neighbouring parts of the island. It can, however, be said that the presence from sediments, derived principally from basic to intermediate metamorphic rocks and from basic igneous rocks, around Timor, corresponds to the rocks which have so far been described from the island by Wichmann (176), Verbeek (168), Imdahl (82), Brouwer (13, 24), Hirschi (76), Simons (151), Tappenbeck (157), de Roever (133) and van Voorthuysen (170). These are:

1. *Crystalline schists.*

Amongst the crystalline schists green schists, namely various amphibolites, glaucophane- and actinolite-schists, epidote-chlorite-schists, epidote-sericite-schists and chlorite-schists take the first place. After them come mica-schists and gneisses, phyllites and quartzite-schists; of these kyanite-garnet-mica schist, staurolite-garnet-mica gneiss and piedmontite-quartzite should be specially mentioned.

2. *Basic and acid igneous rocks.*

These are found abundantly on Timor. Diabase, melaphyre, dacite, andesite and keratophyre, basalt, dolerite, gabbro, diorite, tonalite, spilites, poeneite, granite as well as andesitic and dacitic breccias, volcanic conglomerates and tuffs are found. The ultrabasic rocks: lherzolite, harzburgite, amphibole-peridotite and serpentine rock originating from it, are found also.

Alkali rocks are found locally: bostonite, camptonite, shonkinitic-theralitic rocks, alkali-rhyolite, alkali-trachyte (foyaite), trachydolerite, albitites and alkali-albitites.

3. *Sedimentary rocks.*

The limestones, sand- and claystones and the marls of the various geological periods will not be further discussed here, as detritus of these rocks cannot be specified in the deep-sea sediments, while a part of them, moreover, dissolves during transport and sinking. In some of the sediments detritus of radiolarites and hornstones could be distinguished as such.

It is striking that amphiboles form the chief constituents of the heavy minerals in the sediments lying round about Timor, 377, 161, 163, 157, 158, 126, 125, 119, 121, 122, 115, while in those to the east (120, 118, 116, 117, 111, 112) and to the west (159, 155, 379) epidote minerals predominate in the heavy minerals. The admixture of terrigenous material in 160 is of a similar composition. A relatively higher content of older basic volcanic material is found in sediment 379. Sediments 159, 155, 125 and 126 have a relatively higher content of more acid rocks, as shown in table 17. As regards the two last samples this may be due to detritus of Trias sandstone. Both samples also contain radiolarites and limestone detritus. In sediment 125 the radiolarian forms can sometimes be very clearly recognised: some are transformed into chalcedony, some others are displaced by calcite, while fibrous chalcedony also occurs. The lime particles of this sample are chiefly of terrigenous origin. The mechanical diagram of 125 (fig. 18) shows two peaks, that in fraction 100—50 μ is due to limestone detritus and greyish white or red rock particles, the peak in fraction 20—5 μ is typical of the finer terrigenous sediments.

Sediment 126 consists entirely of finer terrigenous material; it contains the same components as 125 in much smaller quantities.

Radiolarite fragments are also shown in sediments 159 and 377.

Sediment 377 may contain rock detritus from S.W. Wetar as well as material from Timor.

According to de Jong (83) West Wetar is composed of a thick packet of effusive rocks with intercalated marine deposits, such as Globigerina limestones, and Globigerina- and Radiolaria-bearing tuffs. Upheaved reef limestones cover the lower parts of West Wetar. On the south coast and the river beds there he found dacites, andesites and quartz-andesites, tuffaceous rocks and limestones; once only rhyolite to dacite was found. The rocks are sometimes rich in glass. Dacites and andesites containing hornblende, as well as biotite or pyroxenes are found.

Considering the low glass content and the high amphibole content in sediment 377 it would seem that material from Timor is here more plentifully represented than detritus from Wetar.

All the sediments around Timor contain some amount of limestone detritus, but only at St. 125 is the amount considerable.

The mechanical diagrams of sediments 159, 155 and 379 taken west of Timor, are again of a typical Terrigenous Mud composition. The material of the first two samples (table 17) seems to be largely derived from Timor, the mineralogical composition corresponds more to that of the other sediments around Timor than that of sample 379. The latter partly resembles sediment 160.

The Terrigenous Muds lying to the south and east of Timor 119, 120, 121 and 111 and the terrigenous components of the Globigerina Oozes 122, 118, 115, 116, 117 and 112 which also belong to group III, are all very fine-grained. The rock particles of these sediments are mostly undefinable, only in the somewhat coarser sediment 119, near to the coast, andesite parti-

TABLE 16. Mineralogical Composition

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite	apatite	epidote nad zoisite	piedmontite	zircon	tourmaline	garnet	titanite	rutile
118	5		0,5	5		4	1	0,3	0,2	0,2	tr.	0,4		0,3	1	0,2		0,8		tr.		tr.	tr.	
120	2																							
	3													0,1	0,1									
	4			2	0,2	0,5	tr.							0,2	0,2	0,2								
	5	1		10	0,5	3	0,1	tr.			tr.	2,0		0,5	5	1		2,8	tr.		tr.	0 ,1	0,2	tr.
	6																							
117	5		tr.	1		0,3		tr. (21)	tr. (14)	tr. (5)		tr. (7)		tr.	tr.			0,1 (32)		tr. (9)	tr. (2)	tr. (1)	tr. (2)	tr. (4)
116	5		tr.	0,5	tr.	0,2	tr.	tr. (4)		tr. (6)		tr. (10)		tr.	0,1			0,2 (75)		tr. (3)	tr. (1)	tr. (1)		
112	5		tr.	tr.		tr.	tr.	tr.	tr.	tr.		tr.						tr.						
111	2																							
	3													0,5	0,5									
	4	tr.	tr.	0,3	tr.	0,5								tr.										
	5	0,1	0,5	0,3	0,2	0,3		0,5	0,1	0,2		tr.		0,3	0,1	tr.		0,2		tr.	tr.	tr.		
	6																							
379	1																							
	2																							
	3	0,5							tr.	tr.														
	4	8	10	tr.			4	1	1	1		0,2		0,5										
	5	25	20	2		1	8	2	2	2,6	tr.	1,3		1	tr.	0,5	0,3	2,3		tr.		tr.	0,5	
	6																							
160	5	33	22	3		2	10	1,5	2	1	tr.	0,5		0,5	0,2	0,2	tr.	1		0,5		tr.	0,5	
189C	5		5	4,5	0,2	2	0,5	1	0,2	0,6	tr.	0,8	0,1	0,2	0,4	0,1		1		tr.			0,1	
326	P	††	†	†		†			†			†			†	†		††					†	
327	5			23	0,5	13	0,5		tr.	tr.	tr.	4		tr.	3	3		4		tr.	tr.	tr.	0,1	
50	2																							
	3	0,5						tr.		tr.				2	1									
	4	2	1				0,2	tr.		0,2				1	1									
	5	15	10	10		5	4	1,2	0,5	1,2	0,1	0,5		1	1	2,5		1,5		tr.		tr.	tr.	
	6																							
51	S	†	†					†																

cles and chlorite-schist fragments could be recognised, but the majority is undefinable in this sample also.

The mineralogical composition of 120, 121 and 122 greatly resembles that of 119, although the epidote content of 120 is relatively higher. The mineral content of the fractions above 20 μ expressed in percentages of the whole sample, diminishes with the distance to the coast as given below:

No.	119	120	121	122	123	124
% Minerals	9,8	5,1	3,7	1,0	0,5	0,4
distance of coast in km . . .	10	60	90	120	150	160
depth in m	600	2050	2300	1150	450	400

The falling in mineral content, where the depth becomes less, that is, between 121 and 122, is more than between 119 and 121 at increasing depth.

The mineral content of 123 and 124 is too low and the diameter of the minerals is too small to form a distinct picture of the mineralogical composition. The comparatively regular decrease of the mineral content and of the grain-size of the minerals from sediment 119 to sediment 124 makes it very probable that the terrigenous components of the Globigerina Ooze 123 and of the Coral Mud 124 are derived from Timor also.

The mineral content of the Terrigenous Mud 126, the Globigerina Ooze 128 and the Coral

of Terrigenous Muds of Group IIIb.

chromite and picotite	magnetite and ilmenite	pyrite	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Pteropods	Alcyonarian spicules	calcareous sponges	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
		1			0,3	9	24,3	—65—		0,5	0,2		2		2	1	70,7	1	3		4	1	2,2
						3	3	95	2								97						0,3
						30	30,2	64	1,5								65,5	tr.	4		4	0,3	1,2
		1		0,1	0,5	18	23	—69,7—									69,7	tr.	7		7	0,3	0,5
0,1	0,2	3			0,5	10	40	—56—		tr.			0,3		1,7		58	0,5	0,5		1	1	2,5
		3				7	54						0,3	0,2			42,4	2	1	0,1	3,1	0,5	9,9
tr. (2)			tr. (1)		0,3	4	6	—84—		0,1	0,1		2,5		3	2,3	92	1	0,5		1,5	0,5	9,5
					tr.	24	25,2	—72—									72	0,3	2		2,3	0,5	4,3
		2			0,1	22	24,3	—73—		0,1			0,1				73,2	1	1		2	0,5	1,9
						95	95	5									5						1,4
						93	94	6									6						8,8
		tr.				90	91	—9—									9						3,1
		0,1				67	69,9	—30—		0,1							30,1		tr.		tr.		6,4
		1				33	38						tr.				60,3	1	0,5		1,5	0,2	5,5
										†													0,01
								†		†													0,1
							0,5	91	3	1		0,5				2	97,5	tr.	2		2		0,1
		0,5					26,2	39	0,8	0,5		1	0,5		2	19	62,8	1	10		11		1,4
	0,5	2					71	18	1			1	tr.	tr.	2	5	27	1	1		2		12,5
		4					74						tr.	tr.			21,5	2	1	0,5	3,5	1	19,6
	3	tr.				3	84	9	1				tr.		1	3	14	2	tr.		2		16,7
tr.		6			tr.	3	25,7	61,4	0,6	tr.			1		3	3,8	69,8	3	0,5		3,5	1	4,2
		1		0,5	0,5	2	55,3	43,5	0,2	tr.			tr.				43,7	1			1		21,4
								†	†														0,1
						5	8,5	—83,5—								6	89,5	2		tr.	2		0,5
						25	30,5	—67—								1	68	1,3	0,2		1,5	tr.	0,8
	1	0,5				5	60	—26—					1		1	8	36	4	tr.		4		8,8
		0,5				4	72,5						1				22	4	1		5	0,5	21,7
							15										85						

Mud 129 is 1.9%, 0,5% and a „trace", respectively, at distances from the coast of 20 km, 80 km and 130 km. The terrigenous parts of sediments 128 and 129, therefore, also seem to be brought from Timor or Rotti. The mineral composition of 128 resembles that of 126, especially in the presence of radiolarite and pieces of compact limestone in both samples.

The mineral content of sediments 115, 116 and 117 likewise diminishes from north to south, it amounts to 1.3%, 0.6% and 0.4% respectively, with a coastal distance of 80 km, 100 km and 140 km. The mineralogical composition of these samples also indicates, like that of sediment 118, a connection with the Timor-Babar island series.

Samples 112 and 111 cannot be directly compared as in 112 the layer 50—68 cm was sampled and of 111 the upper layer of 0—40 cm was taken. The mineral content of both samples is low, in sample 112 it is 0.3% and in 111 0.5%. The lime content is low compared to the lime content of the other sediments lying between the Timor trough and the Sahoel shelf, this applies in a more marked degree to 111 than to 112. Probably at St. 111 there is a supply of very fine material from the Australian continent. The minerals of sample 111 are distinguished from those of the other sediments belonging to group IIIb by a higher content of augite only, where common green augite occurs beside the usual colourless or light green mineral. (Green augite is also present in sediment 115).

Samples 326 and 327, taken near the northern coast of Mid Ceram, also belong to group IIIb. Dr. Kuenen describes sediment 326 as „fine gravel and sand, with some Foraminifera and fragments of shells" (photo 5). The terrigenous part of this sample consists for 1/4 of rock particles, viz. phyllites and schists, in which much actinolite-epidote-schist occurs. The epidote and zoisite content of the sample is particularly high, it constitutes about a quarter of the mineral parts. The content

TABLE 17. Mineralogical Composition of Terrigenous

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green and brown hornblende	red hornblende	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	piedmontite	kyanite	staurolite	zircon	tourmaline	garnet	titanite	rutile	anatase
257	1																															
	2																															
	3		0,5	0,5																												
	4	24	1	3	0,2	1				tr.			1			0,5			1	1	12											
	5	24	5	19	1	12		0,2	0,3	0,3			1		0,2	1			0,5	5	5		0,5				tr.	tr.	tr.			
	6																															
355	1																															
	2																															
	3		0,2										tr.							tr.	0,2											
	4	1	2	5		2		0,2	1	1			1	tr.		0,5				tr.	4											
	5	2	4	12	tr.	8		0,1	0,7	0,3			0,6	0,2		0,3			0,3	1	3	tr.	0,8		tr.		tr.	tr.	tr.			
	6																															
325	2																															
	3			0,5																												
	4			0,3		0,2													0,2													
	5			18		14		0,5	0,1	tr.			0,1	tr.		0,6			0,5	0,5	1		0,6				0,1		tr.	tr.		
	6																															
354a	S		†	†		†			tr.	tr.			†	tr.						†	†		tr.									
370	5		0,5	4		2			tr. (6)	tr. (9)			tr. (6)			0,1 (13)	tr. (1)		tr.	0,5	0,3		0,4 (54)			tr. (1)	tr. (6)	tr. (2)			tr. (1)	
375	1—5	28	1	6		3		0,3	0,1	0,1			0,2			0,1			0,3	0,3			0,5				tr.		tr.			
	6																															
374A	5	7	8	10	0,3	3		8	0,5	0,5			0,5			0,2			0,5	0,1	0,4	tr.	1				tr.	tr.	tr.	tr.		
376	2																															
	3							2																								
	4	12	2	4		4		6	tr.	tr.			0,1						2	1	0,1											
	5	29	3	12	0,5	10		6	1,5	1,1			0,4			0,4		tr.	0,5	0,5	1		1			tr.	tr.	tr.				
	6																															
247	S	†	†	†		†		†	†	†		tr.	†			tr.			†		†		†				tr.		tr.		tr.	tr.
159	2																															
	3	42	8	15		10		3	tr.	tr.			1						3	1	3		0,5						tr.	tr.		
	4	46	7	9		6	tr.	1	tr.	1			2			3			2	2	4		2					tr.	0,5			
	5	36	6	14		12		1	0,5	1		tr.	1	tr.		1			1	1	2	0,2	2					tr.	1	tr.		
	6																															
155	3	4	1	3		3		1	tr.				3			0,1					1		0,5		tr.		1		10	0,4		
	4	8	3	3		2		3					0,5			0,5			3	3	1		0,2						0,5			
	5	23	15	10		5		6	1	2			2	tr.		1	0,1		1	2	2	0,5	3				tr.	tr.	1	0,3		
	6																															
125	2																															
	3	40																														
	4	35		5	0,2	3	5												1	2	1											
	5	25	tr.	9	0,5	6	3	tr.								0,5			0,2	1	1		0,3				tr.	tr.	0,1			
	6																															
126	2																															
	3																															
	4		tr.	0,1		tr.		tr,					tr.						tr.													
	5	1	1	2,5		1,5	0,1	0,1	0,1				tr.			0,2			tr.	0,2	0,1		0,2			tr.	tr.		tr.			
	6																															
41	5	7	17	20	3	10		1			0,5		9			4			12	1	0,1	3	0,2				0,5	tr.	0,2	tr.		
40	5	8	2	35	3	16		0,1	0,8	0,6	tr.		2,6	0,1		3	0,1		6	2	1	0,3	1,5	0,1			0,5	tr.	0,3	0.3	tr,	
39	5	16	3	28	3	14		0,1	tr.	tr.	tr.		7			2	tr.		7	1	1	0,2	1				tr.	0,1	tr.	tr.	tr.	

of quartz and acid plagioclase forms another 1/4. The content of bronzite and titanite is very small.

St. 326 lies off the coast line which is bounded by the Wai Koehoe and the Wai Makina. According to the researches of Rutten and Hotz (137) the Wai Koehoe rises in an area of glance slates, the river flows through an area belonging principally to the Trias. The Wai Makina and the Wai Ela lying between it and the Wai Koehoe, both rise in the schist formation, which in the opinion of Rutten and Hotz consists principally of phyllites with some mica-schists and green schists; these two rivers also flow through the glance slate Mesozoicum area. The only boulders mentioned are quartz with phyllite in the Wai Koehoe and the Wai Ela and eruptive rock rich in mica in the Wai

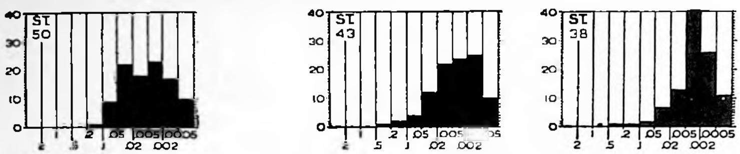
Muds of Group II + III.

chromite and picotite	magnetite and ilmenite	pyrite	glauconite	limonitic casts	clay casts with pyrite and limonite	clay casts with ferric and manganese oxides	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Ostracode valves	calcareous Sponges	coccolithes	discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	limestone fragments	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
		100						100																		0,45
		21		28			51	100																		0,8
		13		60	6		20	100													tr.			tr.		0,4
		3,3		11			35	94	0,5								0,5			1	4	0,2		4,2	0,8	1,9
tr.		1		2			18	96	0,5								0,5			1	3			3	tr.	10,7
		1					27	98												1	1	tr.		1	tr.	25,3
				20		80		100																		0,2
				40		55		95	5											5						0,4
			0,5	50		4	12	67	--32----											32	1			1		1,7
			8	20		4	32	81,8	--18----								tr.			18	0,2			0,2		1,5
0,1	0,3		0,2	10		2	43	89	--10----		0,2					0,1	0,2			10,5	0,5			0,5		5,9
							24	89								0,3				10,5	0,5			0,5		15,0
							35	35	65											65						0,1
							49	49,5	50	0,5										50,5						0,25
		0,3		0,2			54	55,2	30	0,3									0,5	30,8	1	12		13	1	0,8
tr.	0,3	5		0,5			14	56	--35,2 --		tr.		0,8				2			38	3	2	tr.	5	1	4,1
		6					6	80								0,1				17	2	0,5	0,2	2,7	0,3	16,9
		†	†						†	†	†	†	†			†	†		†		†					
tr. (1)	tr.			0,3			0,5	9	89,8	0,2	tr.		0,2							90,2	0,5	0,3		0,8		16,9
	0,1							40	60	tr.										60						38,6
								45	--35----						0,1	19,9				55	tr.			tr.		18,4
	1			2				43	--54----								1			55	1,9	0,1		2		10,1
									99,5	0,5										100						0,2
								2	90	tr.										90		5		5	3	0,2
				1			4	36,2	--42----		0,5						3		3,3	48,8	1	11		12	3	0,6
	1	tr.		0,5			4	72,5	--20----		0,5						3		2	25,5	1	0,5		1,5	0,5	5,3
		tr.					1	63												34	1	1	0,5	2,5	0,5	17,9
	†						†		†												†	†	†			
									†	†	†								†							0,2
								86,5	5		tr.						4		3,5	12,5	tr.	1		1		4,2
								85,5	5		tr.						4		3,5	12,5	tr.	2		2		4,2
	2	0,2						82	5							tr.	7		5,2	17,2	0,5	0,3		0,8		11,7
		0,5						81								tr.				17	1	0,5	0,2	1,7	0,3	18,6
	1						20	49	30								1			31	tr.	12		12	8	0,1
							3,3	31	--20----								2			22	2	33		35	12	0,3
	1	0,5					2	78,5	---8----		tr.		tr.				7		3,5	18,5	2	0,5		2,5	0,5	5,9
		1					0,5	77					tr.							19,5	2	0,5	0,5	3	0,5	19,3
									†																†	0,1
							1	41	--35----		1								3	39		tr.		tr.	20	0,3
								52,2	---6----								15	25	0,8	46,8		tr.		tr.	1	8,0
		0,1						46,8	---8----				tr.				15	30		53	0,2	tr.		0,2		24,2
		1						38					0,1	tr.	0,2	0,5				61,2	0,2	tr.	tr.	0,3	0,5	12,0
							2	2	92	5										97	1			1		0,4
			0,3				3	3,3	92	3,8	0,2									96	0,7			0,7		3,0
			1				4	5,3	--93,8 --		0,2									94	0,5			0,5	0,2	1,8
	tr.	tr.	tr.	0,2			2	9,5	--84,9 - -				0,1			tr.	3	1		89	0,9	0,1		1	0,5	4,9
		0,5					3	28					0,1	0,3	2	1				70	1	0,3	0,2	1,5	0,5	6,0
	3	tr.					5	96,5	2											2	1	0,3		1,3	0,2	15,1
tr.	1	tr.					12	96,5	---1----		0,5									1,5	0,5	0,5		1	1	5,4
	1						12	96,5	2											2	1			1	0,5	19,0

Koehoe and the small Wai Alo. Owing to the lack of details in the description of these regions sediment 326 cannot be compared with the composition of the coastal areas. Green schists, however, seem to contribute an important part to the formation of the sediments, as the Globigerina Ooze 327 also contains a remarkable amount of epidote and actinolite. We are confirmed in the opinion that the terrigenous components of 326 and 327 are derived largely from detritus from northern Mid Ceram by the fact that the grain-size and the contents of terrigenous components in 326, which lies nearer to the coast, are larger than in 327.

Sediment 50 is also classified in group IIIb, it was taken in the Celebes sea by the northern

arm of Celebes. Amongst the rock particles of this sample are found andesite fragments, most of which contain much chlorite and a little muscovite or sericite. The quartz is not idiomorphic and is usually clouded. The common green augite and the highly pleochroitic hypersthene both show signs of decomposition. The green hornblende is pleochroitic from yellowish green to green. The mechanical diagram of sediment 50 (fig. 19) has peaks in the fractions 50—20 μ, and 5—2 μ, which in this case indicates a mixture of medium-grained and fine terrigenous material.



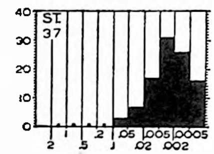


Fig. 19. Mechanical Analyses of Terrigenous Muds of Group III in the Celebes Sea and in Makassar Strait.

St. 50 lies to the north of the bay of Paleleh, where the rivers Talaoe, Kwala Besar and Paleleh have their mouths. According to the researches of Fennema and of Koperberg (92) in the basins of these rivers the rocks which Molengraaff called ,,Woboedoe breccias" are found. These are old andesitic breccias and conglomerates, which are strongly diagenetically altered, while in the conglomerates intrusions are somtimes found. Koperberg records tuffs as well alternating with radiolarites.

Koperberg (92) and Bücking (29) describe from this area hornblende-andesite and -propylite, augite-andesite and -propylite, uralite-andesite, an occasional augite-granitite, olivine-basalt, basalt partly altered into actinolite-fibres, quartz with pyrite grains, black pyrite-bearing schisteous clay, Foraminifera- and eruptive products containing marl, hornstone etc.

The mineral composition of sediment 50 is in general agreement with the above andesites and propylites.

The ,,Coral Sand" 51 raised close to the coast contains only about 15% of terrigenous material. These are andesitic rock particles partially covered by a red-brown ferruginous crust and siliceous rock, with a good deal of green augite which is usually strongly decomposed. Apparently, therefore, this sample contains especially components of old augite-andesite, which is abundant on the west side of the bay of Paleleh.

St. 188 lies near the west coast of Kabaëna. There seems to be little terrigenous material brought here. Sediment 188 is a Globigerina Ooze consisting for more than 60% of Foraminifera and which, according to the mechanical analysis (fig. 25), contains little clay. Although the mineral content is small it is quite clear (cf. table 15 and 25) that the minerals are derived from detritus of crystalline schists, here chiefly amphibolites, and of peridotites, as the principle constituents are actinolite, green to olive-green hornblende and faintly pleochroitic rhombic pyroxene often showing striae with multiple lamellae, as well as plagioclase and quartz. In smaller quantities pale green and colourless augite, epidote and zoisite, muscovite, chlorite, glaucophane, chromite, picotite and garnet occur, while there are also traces of chloritoid, rutile and colourless hornblende. As actinolite predominates the terrigenous components of this Globigerina Ooze are classified in group IIIa; they correspond to the rocks which are described from Kabaëna.

Wunderlin (190) examined material collected by Elbert on Kabaëna; there were amphibolite and phyllite as well as harzburgite, pyroxenite and serpentine.

According to the preliminary geological map that Bothé (9) gives of Kabaëna, this island consists chiefly of Kendari-Mesozoicum (that is mica-schists, phyllites, grafite-bearing glance slates, clay slates, claystones, quartzitic sandstones, quartzites, laminated lime and marble) and peridotites with other eruptive rocks.

St. 193 lies to the southeast of St. 188. The Globigerina Ooze at this station contains Batoe Tara ash and terrigenous material. The latter is shown by the mineralogical composition, especially by the presence of glaucophane and chromite-picotite (table 25), to be derived from the northern

areas lying round the bay of Boni. In the preponderance of actinolite amongst the heavy minerals of the terrigenous material it most resembles the terrigenous components of 188.

Sediments 189 I—V and 189 A—C near the coast of South Celebes consist of alternating layers of Globigerina Ooze and Terrigenous Mud. The great variation in the content of calcareous debri in the different layers is very striking. This calcareous debri may be derived from upheaved coral reefs in the Bone mountains, which would account for the great resemblance between a sample such as 189A to 186 and 187.

Although the amount of terrigenous material in the successive layers from station 189 vary considerably, there is very little variation in the mineralogical composition of the material (table 16 and 25). It contains more detritus of basic igneous rocks than the other sediments in the bay of Bone. Of the heavy minerals by far the most abundant are monoclinic pyroxene, epidote, hornblende and actinolite. Only a few green augites are idiomorphic, the other monoclinic pyroxenes are pale green, colourless or pale violet. The rhombic pyroxene is strongly lamellated and faintly pleochroitic, often much altered. Fibrous green hornblende and actinolite occur beside prismatic forms.

t'Hoen and Ziegler (79) report that on the southern arm of Celebes in the eastern mountains, that is the Bone mountains, principally andesitic rocks of a diabase character occur, while leucite-bearing rock, trachyte and liparitic breccias are also found. The mineral composition of the samples 189 correspond to this in so far that basic igneous rock detritus predominates, the components of slightly metamorphic and ultrabasic rock (grafite-bearing muscovite, rhombic pyroxene, actinolite, glaucophane and chromite) should then be regarded as foreign matter. It is possible that these are derived from a more northerly area; the transportation of material brought down by the rivers into the Bay of Boni in a southerly direction is acceptable and is rendered probable by the mineral composition of the samples 193, as well as by the mineralogical and mechanical composition of sediments 190 and 192 (cf. group I p. 135).

Finally the samples raised in the Makassar Strait, 38 and 43 (table 15) and samples 39, 40 and 41 (table 17) which are mixed with recent-volcanic material and detritus of acid eruptive rocks, belong to group IIIa.

St. 40 and St. 39 lie 10 km and 100 km respectively from the coast of Mid Celebes at the level of the mouth of the S. Lariang. As described by Abendanon (1) the Lariang enters the sea in a stream of 100 m width and 3 m depth, the mouth is not sanded up and deepens rapidly towards the sea. This large river, with its numerous tributaries is capable when in flood of bringing down large quantities of material with great rapidity.

This accounts for the Terrigenous Muds 39 and 40 (with a small admixture of recent-volcanic material) both belonging to the medium-grained sediments (cf. fig. 12), in contrast to the sediments 38 and 37 (fig. 19) deposited on the western slope of the Makassar Strait.

The mineral composition of samples 39 and 40 show a great resemblance to each other. In the acid plagioclase albite is found. The augite is colourless or pale green, the rhombic pyroxene is faintly to moderately pleochroitic from pink to green, sometimes from yellow to green. Pyroxenes and hornblendes show decomposition, the green hornblende is sometimes fibrous. The small quantities of red hornblende, piedmontite and chromite found in 40, are absent from 39. Amongst the rock particles amphibolite and epidote-chlorite-schist can be distinguished.

According to Abendanon (1) the boulders in the lower reaches of the Lariang are of the same composition as the central mountain land along the upper reaches of this river, which is called Koro. These rocks are amphibole-granite, granitite, amphibole- and augite-biotite-granodiorites, amphibole-diorite, biotite- and amphibole-gneiss, amphibolites, quartz-porphyr, biotite-liparite, various, usually biotite-bearing trachytes and andesites and marly arkose sandstone. To these may be added for the upper reaches of the river and its tributaries, aplite, mica-schists rich in graphite, phyllites, epidote-chlorite-schists, eklogites, a little uralite- and saussurite-gabbros, an occasional amphibole-peridotite, serpentine, shonkinite, leucite-basalt and hornstone. The amphibolites are augite-, plagioclase- and albite-amphibolites. Further conglomerates, sand- and clay-stone were found, which are composed of various of the above mentioned rocks. Brouwer (25) examined the Koro river and the various tributaries in the upper bed and found moreover dacite, diabase and phyllitic slates to add to the list.

Material of all these rocks, with the exception of the alkali rocks and the hornstone, are represented in sediment 40 (orthite is part of the granites and the aplite).

The rocks which yield most detritus are the acid eruptive rocks and amphibolites in samples 40 and 39, which are therefore classified in group II + IIIa on the map. These sediments moreover contain a low percentage of fresh volcanic ash from the Oena-Oena (cf. p. 126 etc.).

The more northerly sediment 41 is of similar composition to 40 and 39, but the content of Oena-Oena ash is somewhat higher, as well as that of basic plagioclase, while the ordinary pyroxenes are absent, enstatite-augite and enstatite on the other hand are present.

The mechanical composition characterises 41, as well as 40 and 39, as a medium-grained sediment (fig. 12).

The material of this sediment is in all probability supplied both by the rivers entering the Paloe bay, of which the Si Paloe is the most important, and by the small streams which flow into the sea on the west coast of the „neck" of Celebes.

The researches of Abendanon and Gisolf (59) and of Brouwer show that in the river basin of the Paloe the same species of rocks are found as in that of the Si Lariang, with the exception of a few alkali rocks. Basic to ultrabasic, often schisteous rocks are more common in the valley of the Si Paloe, however; amongst the amphibolites moreover actinolite-schists are found.

Along the western bank of the Paloe bay basic to intermediate volcanic rocks and tuffs are found, further phyllitic slates and radiolarites. From the east coast of the Paloe bay Brouwer records sand- and clay-stones, and conglomerates, the material consisting of granodioritic rocks, granites gneisses and amphibolitic rocks. Nothing is found in sediment 41 of the limestones and lime-bearing rocks near the Paloe bay, so that they need not be enumerated here.

More to the north, in the „neck" of Celebes, Brouwer found in the Si Tondopada granitic to granodioritic rocks and microdiorites to dioritic porphyres, further andalusite-bearing biotite-schists, biotite-muscovite-schists with sillimanite and garnet or with andalusite and staurolite (which minerals are not found in 41), mica-gneiss and amphibolites.

Bücking has described from the Tamboe bay with the islet of Zuidwachter directly east of St. 41, granites, diorites (some with secondary uralite, actinolite and epidote), quartz-trachyte, clay slate, clay slate conglomerates, limestones and marls.

Although all the above rocks are not represented in sample 41, the composition of this sediment corresponds to the most general components.

The same cannot be said of sediment 43 (fig. 19). According to the researches of Bücking (29), Ahlburg (142) and Brouwer (25) the neighbouring part of North Celebes is principally composed of granites, diorites; gneisses, mica-schists and chlorite-schists; phyllitic slates and phyllites with intercalated sandstones, diabase, slate, quartzites etc.; limestone and coral rock. Bücking describes hornblende-andesite as well, from the bay of Dondo, St. 43 lies just to the west of this bay. There are no large rivers in this area, so that there is probably not much transport of material, possibly the transport to greater distances is confined to the finest particles.

The mineral composition of sample 43 shows a higher content of basic volcanic material than would be expected, considering the above species of rocks in this part of Celebes (table 15). But it should here be remarked that in fraction 6 the muscovite and quartz content is higher than in fraction 5; so that in the finer fractions detritus of rocks from N.E. Celebes may take a greater part. The presence in this sample of idiomorphic green hornblende contained in volcanic glass makes it probable that a certain amount of recent-volcanic material, carried by marine currents, contributes to the sediment.

Sample 38 is a very fine-grained sediment (fig. 19) with only a small mineral content. The amount of Oena-Oena ash is less than in sediment 39, although the percentage in the minerals of the sandfractions is higher than in sample 39. The small mineral content makes it difficult to classify this Terrigenous Mud. Probably the fine material from West Celebes and the components transported in the length of the Makassar Strait are chiefly deposited here and to a less extent material derived from Borneo. This conclusion is unexpected, as the delta of the great Mahakam river lies at only 50 km distance, which can be observed within the 200 m line at only 20 km distance as a large promontory at the foot of Borneo. Sample 38, however, shows more resemblance to 39

and 43 than to sample 37, which has a higher quartz content and a relatively higher epidote content than the three first mentioned samples.

Sample 37 belongs to the sediments which cannot well be brought into any of the 5 groups of Terrigenous Muds. There proves to be a very fine sediment deposited at this station at only 60 m depth (fig. 19), of which the lime content it not more than 6.7%. This indicates that the great Mahakam river by whose delta St. 37 lies, certainly transports a great deal of material, but that very little sand reaches the sea. This is partly explained by the fact that in the mid basin of the Mahakam river, as described by Witkamp (189) a flat sunk area is found, where the river shows all the phenomena characteristic of lower reaches, meandering through lakes and pools and depositing thus much of the material it has carried. Subsequently the river breaks through the coastal mountains of some 80 m high young-tertiary, consisting of sandstones and slates, intercalated with coal layers and an occasional limestone bank. In the lower reaches and in the delta again material is deposited, more and more as the current subsides. It is thus natural that chiefly material from the coastal area has contributed to sediment 37. Moreover a large part of the basin of the Mahakam consists of Tertiary (bibl. 163, 186, 187, 189) which, according to Witkamp (188, 189), Rutten (139) and Ubaghs (163) is locally intruded by younger effusive rocks, chiefly basaltic lavas.

The tertiary mountains are composed of sandstones, conglomerates, marls and limestones. The sandstones are quartz-sandstone, in which according to Witkamp (186) weathered felspar and a few coloured minerals take part. Retgers (127) has described sandstone and sand derived from the region between Pelarang and Samarinda collected by Hooze. There are quartz-sandstones to porphyrite-sandstones; some loose sand contains quartz, actinolite, brownish green hornblende, pale green augite, a little muscovite, chloritic products, kaoline and apatite.

Pre-tertiary rocks were found by Ubaghs and Harting (68) at the sources of the Kedoeng Kepala (the S. Atan, the S. Poh etc.), a large left-hand tributary of the Mahakam. Molengraaff's Danau formation is here represented by arkose sandstone, radiolarites, schists and limestones and by metamorphic, sometimes highly epidotised basic and ultrabasic eruptive rocks. Locally basalt, andesite, dacite, liparite, and quartzporphyry occur. According to Harting black, red and green schists lie discordantly upon the Danau formation.

The mineral composition of sediment 37 (cf. below table 18) corresponds to that of the tertiary sandstone in a preponderant content of quartz and felspar, and a small content of heavy minerals. Amongst the heavy minerals affected epidote predominates. The hornblende is green and brown, the augite colourless, the hypersthene moderately pleochroitic from pink to green. The pyroxenes, therefore, do not show the habitus usual for these minerals in basalt or andesite.

The composition of the heavy minerals is distinguished from that of the samples in group IV by the low content of zircon.

IV. Terrigenous Muds which contain chiefly detritus of quartziferous sediments.

These Terrigenous Muds are characterised by a comparatively high quartz content, and by a high percentage of zircon (sometimes zircon and tourmaline) in the heavy minerals.

According as a greater quantity of eruptive material is mixed with the sediment the zircon content in the heavy minerals becomes proportionally lower. If the admixture consists of basic volcanic material with its high content of heavy minerals the zircon content is naturally depressed, as in sample 25 (table 18); the quartz content, however, remains relatively high, showing that the admixture of basic volcanic material is of subordinate importance.

It is remarkable that all sediments belonging to group IV occur in the vicinity of tertiary regions, namely near East Borneo, by Madoera, by S.W. Borneo and by New Guinea and the Kei, Aroe and Tenimber islands.

From the stations N.E. of Netherlands Borneo samples 305, 309^L, 47, 44 and 45 have been received and examined. In mineralogical composition these samples show a considerable resemblance, although sample 44 contains fewer components than the rest. Samples 47 and 309^L, raised near together, are practically indentical, so that the minerals in 309^L were not counted and the mineral composition of that sample is not entered in table 18. The rock particles of these sediments often

contain much chlorite. The quartz is angular with fine inclusions, occasionally showing undulose extinction. The quartz is often surrounded by delicate scales of a mica-like mineral. The augite is colourless or pale green and affected. The rhombic pyroxene is faintly to moderately pleochroitic, from rosy-yellow to green and like the augite sometimes shows ragged ends. In sample 305 alone there is some slightly decomposed highly pleochroitic hypersthene. The hornblende is greenish brown to brown, a few idiomorphic green hornblendes contained in volcanic glass occur, they resemble those of the samples raised further east in the Celebes sea. The zircon is mostly colourless, in sample 305 it is sometimes pinkish purple or pink.

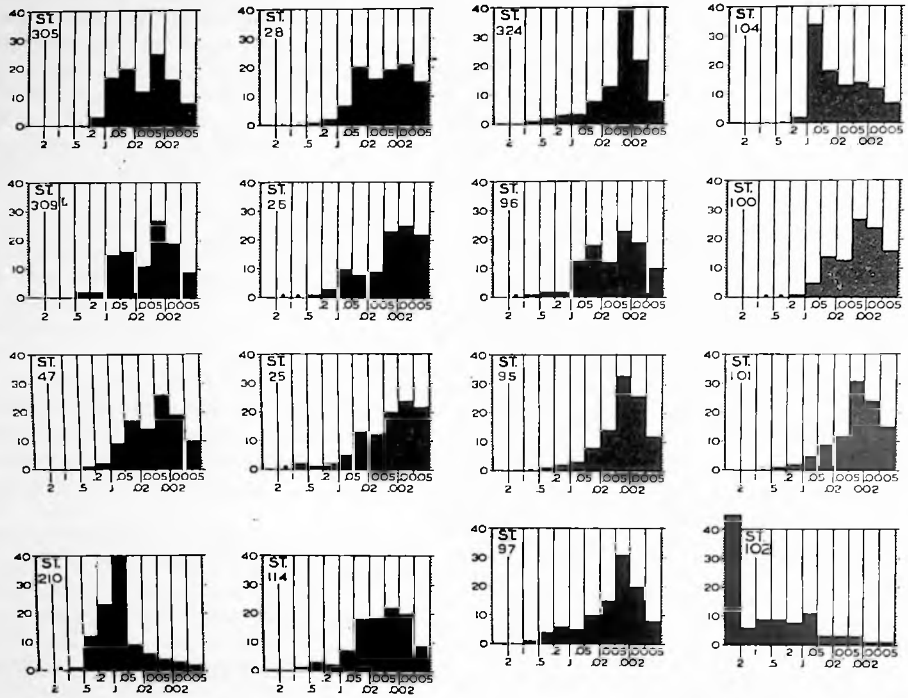


Fig. 20. Mechanical Analyses of Terrigenous Muds of Group IV.

The mechanical diagrams in fig. 20 indicate for sediments 305, 309^{L} and 47 that terrigenous components with a principle diameter of 100—20 μ are mixed with many terrigenous clay particles.

The terrigenous components of these sediments may be regarded as detritus from N.E. Borneo, chiefly brought down by the large rivers the Beraoe, the Boelongan and the Serajap. The basin of these rivers is only partly known. The lower reaches flow through tertiary regions. The upper reaches of the rivers lie in the pre-tertiary.

Harting (68) reckons the pre-tertiary along the Beraoe to the Danau formation, it is composed of slates, quartzites, siliceous limestones and hornstones with Radiolaria, and locally of sandstones, basic eruptive rocks and granite. Similar rocks have been described by Bücking (31) from its tributary the Kelai and boulders by Escher (51). They also mention quartz-porphyry, igneous breccias, tourmaline-bearing breccias, quartzitic sandstone, injected with quartz-amphibolite, mica-sandstone and greywacke.

According to Rutten (141) and Harting the tertiary is represented by limestones some of which contain a certain amount of conglomerates and sandstones formed from radiolarite and quartz and material of rhyolitic and dacitic tuffs; further by marls, calcareous sandstones, partly carbon-bearing sandstones and claystones.

Krökel (94) has described rocks collected by Herbordt from the basin of the Boelongan. Amongst

these are granite, diorite, dacite and many basic eruptive rocks, especially augite-andesite, silicified andesite, andesite-tuff and -breccia; as well as quartz sandstone, arkose sandstone and flinty shale. Limestone, calcareous marl and clay shale are not further described.

The young tertiary formation which occurs on the coast south of the Boelongan delta and on the islands of Tarakan, Boenjoe etc. contains lignitic coal, loose sand, siliceous rocks, clay marls and calcareous marls, which are not described. Igneous rocks are here absent.

No publications are known to me concerning the region of the Serajap.

From the island of Maratoea, near which the Coral Mud 45 lies, Rutten (141) has described a limestone and a calcareous sandstone. The latter contains much dusty quartz, less plagioclase and very little muscovite; these minerals are cemented by carbonate and limonite.

Kuenen (97) reports that the island of Maratoea, recognised by Niermeyer as an atol, consists of a horse-shoe-shaped rim of raised reef limestone, partly encircling a shallow platform studded with a few limestone islets. There are a few patches of sand. The sand has not been further examined.

Material from radiolarites was not found in the above deep-sea sediments. Siliceous rocks with fibroradiate chalcedony occur in sample 44. The sediments appear to contain chiefly detritus of acid eruptive rocks with material of tertiary sandstone and a little detritus of basic eruptive rocks. The minerals correspond to the constituents of the above species of rocks.

Sediments 28, 26 and 25 in the Java sea, show more variety in mineralogical composition than those deposited in the deep Celebes sea N.E. of Borneo. This might be expected, as in a sea of 60—80 m depth the sandy minerals sink rapidly, while during transport over a greater distance in a deep sea a greater mixture of sandy material can take place.

The mechanical analyses (fig. 20) show that the clay-content of samples 26 and 25 is high, while sample 28 is of a somewhat less fine composition. Stations 26 and 25 lie in a region which is given as heavy clay in the map of the bottom sediments of the Java sea by Mohr and White (bibl. 114). This region of heavy clay extends from the coasts of E. Java and Madoera to 100 km from the coast. North of this region gravel, sand and loamy sand or sandy loam occur. Close to the coast of Borneo clay is found locally. Molengraaff (114) pointed out that the way in which gravel, sand and clay are distributed in the Java sea can be explained by considering the northern region, consisting of richly quartz-bearing sand, as submerged land, corresponding to the granite and sandstone so plentiful on Borneo, Billiton and Bangka.

Sediment 28 seems to belong principally to the relict sediments, upon which Tambora ash and perhaps some clay particles are deposited. It appears from the presence of a Globigerina Ooze with a low content of terrigenous material at St. 29 that here at the edge of the Soenda shelf the supply of terrigenous material is poor. This agrees with the fact that as reported by Krol (95) the rivers of S.E. Borneo flow through low marshy ground while the mouths are sanded up, so that little terrigenous contribution to the Java sea can be expected from there. The rivers of S.E. Borneo mostly arise in mountains which consist of basic and ultrabasic rocks. The presence of such material in sediment 28 could only be intimated by traces of hornblende and chromite, as the basic plagioclase, the augite, the biotite and the apatite should be chiefly regarded as constituents of the Tambora ash. The rivers of S.E. Borneo then flow through tertiary coastal regions of which the mineralogical composition is unknown. It is most probable that they carry off practically nothing but clay particles. A correspondence in mineralogical composition of sediment 28 and the material of the tertiary coastal districts, moreover, might indicate either the presence of a relict sediment at St. 28 or deposited material; in this case the mechanical composition of the material at several spots would have to be compared to be able to draw conclusion.

No Tambora ash was found in samples 25 and 26. The content of volcanic glass in these samples is low, so that their basic young-volcanic material seems to have been brought by rivers, moreover the biotite is yellow and decomposed, seldom green, the brown biotite of the Tambora ash is absent from it. The subordinate amount of basic volcanic material in both samples is characterised by little altered basic plagioclase, highly pleochroitic, sometimes beautifully idiomorphic hypersthene, pale green augite and idiomorphic apatite; the hornblende in these samples is partially altered. It is likely that the young-volcanic material has been brought down by the Solo river or even the Kali Mas, which carries off almost exclusively young-volcanic material.

TABLE 18. Mineralogical Compositio

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite	apatite	epidote and zoisite	kyanite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	anatase	chromite and picotite	magnetite and ilmenite	pyrite
305	2 3 4 5 6	14 7	0,1 2	† 20 26 30	0,2	† 28 37 43	0,1 1	0,2	0,4	tr. 0,2	0,1	tr.		tr. 0,5	1	1		0,4			0,8	tr.	0,1		tr.		tr.	tr.	† 20 2 5 15
45	5		1	4		3	tr.	tr. (7)	0,1 (13)	0,2 (27)	tr. (1)	0,1 (10)		tr.	0,1	0,5		0,1 (15)			0,1 (18)	tr. (1)	tr. (1)	tr. (3)	tr. (2)		tr. (2)	0,1	tr.
44	S	†		†	†	†						tr.		tr.				tr.			tr.	tr.						tr.	
47	3 4 5 6	tr. 6	2	tr. 0,3 25	tr.	tr. tr. 33	1	0,1	0,2	0,4	tr.	0,2		0,2	0,3	0,5	0,3	0,2			0,2	tr.	tr.	0,1	tr.			tr.	2 1 2 3
28	1 2 3 4 5 6	1	0,1 2	0,2 0,2 4		7	0,1 2 12	tr. 0,3 (67)		tr. (3)				1 2 0,5	0,5 0,2		tr. (8)	tr. (5)			0,1 (15)	tr. (½)	tr. (½)		tr. (½)		tr. (½)	0,3	0,1 0,3
26	1 2 3 4 5 6	tr. .r.	2 2	1 6		4 22	0,3	0,2 (24)	0,1 (14)	0,3 (30)	tr. (1)	tr. (1)	tr. (½)	2 0,2 0,1	1 tr. tr.		0,1 (5)	0,1 (8)			0,2 (15)	tr. (1)			tr. (0,2)	tr. (0,1)	tr. (0,2)	0,3	0,3 0,5
25	1 2 3 4 5 6	0,3	2 3	0,5 6		0,5 10	1 2	0,1 0,2 (32)	0,1 (15)	0,3 (45)	0,1 tr. (1)			3 0,1			0,1 (5)	tr. (½)			tr. (1)	tr. (½)						0,2	1 1
210	1 2 3 2 5 6	† 30 50 50 45		2 12 14 15		3 25 30 30		0,3 0,5		tr. tr.				† 0,3	1 0,3 0,5 0,5	0,3 0,3 0,3		tr. tr.	tr.	tr. tr.	0,3	tr. tr.	tr.		tr.	tr.		tr.	
87	5		tr.	6		10	tr.	tr. (2)	tr. (4)	tr. (12)		tr. (2)		tr.	tr.			tr. (4)			0,1 (36)	tr. (12)	tr. (2)	tr. (4)	tr. (1)				0,5
91	5		0,5	10	tr.	15		tr. (6)	tr. (7)	tr. (14)		tr. (2)			tr.	1		tr. (21)		tr. (3)	tr. (20)	tr. (6)	tr. (5)		tr. (2)		tr. (14)		1
324	2 3 4 5 6		0,2	5	0,1	tr. 8	0,3	tr. (21)	tr. (7)	tr. (7)	tr. (1)			0,1	1	0,1		tr. (4)			tr. (37)	tr. (4)		tr. (4)	tr. (4)				1 4 6
96	1 2 3 4 5 6		1	1 3		1 8		tr. (12)	tr. (8)	tr. (10)		tr. (2)		tr.	1	0,2		tr. (12)			0,1 (28)	tr. (12)	tr. (4)	tr. (1)	tr. (1)		tr. (7)	tr.	2 2 2
95	2 3 4 5 6		tr. tr. 0,5	0,3 tr. 4	tr.	tr. 7	tr. 0,5	tr.	tr.	tr.					tr. 1	0,5		tr.			tr.	tr.	tr.						tr. 2 3
97	2 3 4 5 6		0,3	5	0,1	9	0,2	tr. (26)	tr. (8)	tr. (19)				0,3 tr. tr.	tr. 2	0,2		tr. (11)			tr. (21)	tr. (5)			tr. (2)		tr. (8)	tr.	2 4

barite	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Lamellibranch fragments	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	marl fragments	calcospherolites	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
								†																					0,13
				2	70	19	1																20					10	0,24
				10	89,3	6	0,2																6,2	1	0,5		1,5	3	2,8
				3	96	2	tr.																2	1	tr.		1	1	17,2
				4	85																		7	5,9	0,1		6	2	19,6
		1	0,3	1	11,7	32	5	0,5			1						2					42,5	83	4	1		5	0,3	11,8
							†				†																		
				96	98																			0,7	0,2		1	1	1,4
				92	93,6	2																	2	0,4	2		2,4	2	1,8
				25	96,5	1											tr.				tr.		1	2	tr.		2	0,5	9,0
				6	91,5																		1	6	1	tr.	7	0,5	17,3
									†													†							0,05
				†		†	†	†	†	†																			0,13
				78	79,8	4	4	3		0,1	0,1	0,5										8	19,7	0,5			0,5		0,6
				66	70,5	8	10	3			1											7	29	0,4	0,1		0,5		1,8
		0,1		36	63,5	10	14	2			0,2					0,5	tr.					9	35,7	0,8	tr.		0,8		6,8
				10	58,4												1						41	0,5	0,1	tr.	0,6		20,2
							†	†	†																				0,02
				3	3	3	30	30	8	10	1	1			2							12	97						0,3
		1		2	6	18	24	10	5	5	1	1										30	94	tr.			tr.		0,7
		29,8		1	38	12	24	8	2	1	2											12	61	1			1		2,7
		16		5,5	53,5	9	14	2	1	0,1	2					0,1	0,3					17	45,5	1			1		9,8
				6,5	62												1						38	tr.			tr.		7,9
							†	†	†																				0,2
							40	12	14	2		1			1							30	100						1,8
						1	25	15	6	1	0,5	2					1					48,5	100						1,0
		3		5	15,2	12	24	14	3	2	2	0,5										26,8	84,3					0,5	1,8
		2	0,1	12	37,5	10	24	3	1,5	0,3	2						0,5					20	61,3	1	tr.		1	0,2	5,3
				5	65												1						34,8	0,2			0,2		13,0
						†																†							0,4
		1			37	22	2	2														35	61					2	1,4
					87,6	4	0,3									0,1					4	4	12,4						11,6
					95,2	2															2	0,8	4,8						22,7
					92	1															5	2	8						39,6
					91,5																		6	1	0,9	0,1	2	0,5	9,3
tr. (1)	tr. (20)	4	1	5	27	--72--		0,5													0,5		73	tr.	tr.		tr.		7,5
		10	2	2	41,5	40	10	1									tr.					7	58	0,5			0,5		7,8
				97	97	2																1	3						0,5
				95	95	5	tr.																5						2,0
				91	92	8	tr.	tr.															8		tr.		tr.	tr.	2,9
	tr. (11)	1	0,5	55	75,3	22	1	tr.															23	1	0,2		1,2	0,5	3,1
				32	78																		18	2	1	tr.	3	1	7,6
						†	†						†									†							0,1
				2	2	85	10						1									2	98						0,9
				3	3	--88--		0,3		1	1											4,7	95	2	tr.		2		1,8
		1	1	3	9	--77--		0,5		2	3											4,5	87	2	1		3	1	2,3
	tr.	1 (3)	tr.	2	18,7	--46--		1			0,5					0,5	1			tr.		30,3	79,3	2	tr.		2	tr.	12,6
				1	32															0,5			64	2,5	0,5		3	1	17,7
				92	92	--6--																2	8						0,2
				85	85,3	--12--																	12	2,7	tr.		2,7	tr.	1,1
				80	80	--17--																1	18	1	1		2	tr.	2,3
		0,5	tr.	50	66	--28--		tr.									tr.				3	0,5	31,5	1,8	0,2	tr.	2	0,5	2,5
				20	68															0,5			28	2,5	1	tr.	3,5	0,5	7,9
				98	98	1																1	2						0,55
				97	97,3	--2,7--																	2,7						3,9
				94	94	--5,5--		0,2															5,7		0,3		0,3		5,9
		tr.	tr.	60	79	--19--		0,2												tr.	0,8		20	0,5	0,3		0,8	0,2	5,0
				35	73															0,5			23,5	2	1	tr.	3	0,5	10,4

Table 18. Mineralogical Composition

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite	apatite	epidote and zoisite	kyanite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	anatase	chromite and picotite	magnetite and ilmenite	pyrite
104	2																												
	3					1									tr.														
	4		1	10	0,3	25				tr.				0,3	3	2													
	5		0,5	18	0,5	44		tr.	tr.	0,1				0,1	12	2		tr.			0,1	tr.							0,3
	6																												2
103	5		same as 104																										3
100	2																												
	3						tr.							2	2														
	4			0,2		0,2								0,2	1														
	5			16	tr.	40		tr. (4)	tr. (2)	0,5 (40)	tr. (3)			0,2	5	1		0,2 (12)			0,2 (12)	0,2 (12)	tr. (3)	tr. (4)	tr. (3)	tr. (1)	tr. (1)		3
	6																												4
101	2																												
	3			tr.										0,1	tr.														
	4		tr.	0,3		0,7								tr.	0,2														
	5		tr.	2,5		5,5	0,1	tr. (9)	tr. (7)	tr. (7)				tr.	1	tr.		tr. (4)			0,1 (40)	tr. (8)		tr. (1)	tr. (4)	tr. (1)	tr. (1)	tr.	3
	6																												5
102	1																												
	2																												
	3																												
	4			0,5		1,5									tr.	tr.													
	5			2		4	tr.	tr. (7)	tr. (3)	tr. (11)					tr.	tr.		tr. (7)			tr. (44)	tr. (9)	tr. (4)	tr. (1)	tr. (7)	tr. (1)			
	6																												
98	S			†		†									†	†						tr.							†
105	5			0,3		0,7		tr. (9)	tr. (12)	tr. (7)								tr. (3)			tr. (14)	tr. (4)			tr. (1)				1
106B	5		tr.	0,5		1,5		tr. (16)	tr. (9)	tr. (16)				0,1	0,1			tr. (9)			tr. (23)	tr. (24)	tr. (3)						tr.
106A	1																												60
	2																												50
	3													0,5															24
	4					tr.																							5
	5			1		2,5				tr.					tr.	tr.		tr.				tr.							14
	6																												10
107	5		tr.	8	0,1	18		tr. (5)	tr. (15)	tr. (20)		tr. (16)		tr.	1	0,5		tr. (16)			tr. (9)	tr. (15)		tr. (3)	tr. (1)				1
108	5			0,5		1,5		tr. (18)		tr. (27)		tr. (10)		0,1	0,2			tr. (9)			tr. (16)	tr. (9)	tr. (2)	tr. (4)					1,5
109	5		tr.	1	tr.	3		tr. (23)	tr. (17)	tr. (24)		tr. (10)		0,1	0,2			tr. (12)			tr. (2)	tr. (10)							2
110	5		tr.	0,5		1,5		tr. (9)	tr. (5)	tr. (8)					tr.	tr.		tr. (22)			tr. (36)	tr. (10)	tr. (3)		tr. (7)			tr.	1
114	2																												
	3																												1
	4		tr.	tr.		tr.								tr.	tr.														2
	5		tr.	7		12		tr. (11)		tr. (10)		0,1 (15)	tr. (1)	0,5	5	0,1		0,2 (35)			tr. (9)	tr. (12)	tr. (2)	tr. (1)			tr. (2)	tr.	2
	6																												1
37	1																												
	2																												
	3			0,5		0,5																							
	4					0,1								0,5	0,2	0,1													
	5		0,3	4		6	tr.	tr. (15)	tr. (9)	tr. (12)	tr. (2)	tr. (15)		0,3	tr.	0,3	tr. (1)	0,1 (40)			tr. (3)	tr. (2)						tr.	1
	6																												1

But the principle component of both samples is formed by material rich in quartz. Sediment 26 is distinguished from 25 and 28 by containing also affected hypersthene, which is faintly pleochroitic from pink to greenish blue and by the presence of traces of actinolite, glaucophane and pale brown anatase.

of Terrigenous Muds of Group IV.

barite	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Lamellibranch fragments	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	marl fragments	calcospherolites	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
				†		†																						†	0,1
		1	tr.	55	57	17	0,3																17,3	0,2	0,5		0,7	25	0,2
		1	1	6	49,6	22,5	0,5	2		1	1					0,2					0,8	4,4	32,4	1	2		3	15	2,1
		1	0,5	4	83,1	7,2	0,3	2								1	tr.			tr.	4	0,8	15,3	0,5	0,1		0,6	1	34,1
				7	84															0,5			14	1	0,4	0,1	1,5	0,5	17,8
		6		10	27															0,1			73	tr.	tr.		tr.		6,3
				†		†																							0,01
				90	94	5																1	6		tr.		tr.		0,35
				86	87,6	10											tr.					0,2	10,2	0,2	1		1,2	1	0,7
	tr. (3)	1	0,5	12	80	12	0,3	0,3								0,3	tr.			0,5	5	0,3	18,7	0,5	0,3		0,8	0,5	4,8
			tr.	10	69															2			27	1,7	1	0,3	3	1	13,6
				†		†	†																						0,1
				83	83,1	--16----		0,5															16,5	0,2			0,2	0,2	1,5
				72	73,2	--25----		0,2															25,2	tr.	1		1	0,6	2,1
	tr. (18)	0,3	tr.	28	40,8	--54----		1								tr.	0,1			tr.	2,5		57,7	0,9	0,1		1	0,5	4,9
				22	43															1			52,5	2	2	tr.	4	0,5	8,6
						0,1	10	3	2		1			-12--		0,1		50				20,8	99	1			1		6,5
						41	9	2	2	1	1			--5--		0,5		30			0,5	7,5	99,5	0,5			0,5		8,8
						30	3	3			2	0,1		--5--		1		35			0,5	19,4	99	1			1		9,0
				0,5	2,5	18	4	2			2	0,5				1	0,5	50			1	18	97	0,5			0,5		7,5
	tr. (6)	0,1		0,3	6,5	--10,5--		0,3								2	3	70	0,1		3	4	93	0,5			0,5		10,9
				1	7												1			1			92	1	tr.		1		3,4
		†				†	†	†													†			†					
	tr. (50)	1		4	7	86	2	1			0,5						tr.					3,2	92,7	tr.			tr.	0,3	18,1
		3	0,5	1	6,7	--90----		0,5									tr.					0,8	91,3	1	0,5		1,5	0,5	14,5
		40			100																								0,5
		8			58	--40----		1														1	42						0,6
		20		0,5	45	--55----																	55						0,6
		11	1	6	23	--75----		1														1	77						0,8
		3	0,5	8	29	--70----		0,5														0,5	71	tr.			tr.		1,2
				6	71												tr.			0,2			28	tr.	tr.		tr.	1	3,6
		2	0,2	6	36,8	--61----		1									1			tr.			63	0,1	0,1		0,2		10,7
	tr. (4)	1	0,2	10	15	--82----		0,5									0,1					0,2	82,8	1	1		2	0,2	6,4
	tr. (2)	0,5		17	24	--75----		0,3									0,2						75,5	0,3	0,2		0,5		5,2
		1		12	16,2	--55----		2			1					1	3					20,5	82,5	1	tr.		1	0,3	12,7
						98	2																100						1,1
					1	97	1																98	0,5	0,5		1		2,6
			0,3	0,5	3	92	1	tr.															93	0,5	3		3,5	0,5	1,9
	tr. (2)	tr.	3	2	32	64	0,9	0,1													1		66	0,8	0,2		1	1	6,8
			1	4	45												0,2			0,1			50	2	2	tr.	4	1	17,7
							†		†																				0,03
							46	8	35		2	2										7	100						0,07
				50	51	11	18	5	12	0,3	2	0,3											48,6	0,4			0,4		0,16
				70	71	7	9	3	7,7	0,3	1												28	1			1		0,3
				40	52	16	17	1	6	0,2	0,8					1	3						45	3	tr.		3		2,7
				20	70												3						28	2			2		6,9

Concerning the origin of the material of the samples 25 and 26, 35 cm and 43 cm thick respectively, we may again ask if we have a relict bottom to deal with. It is not probable that the small rivers on the north coast of the arid Madoera have contributed material to form these sediments lying 60 and 40 km from the coast. It is quite possible, however, that the Solo river may have taken

part in the formation. This river, with its tributaries, of which the upper reaches come chiefly from recent-volcanic, andesitic territory, flows further through neogene and quarternary marls, claystones sandstones, limestones, volcanic tuffs and breccia.

An examination of the sand of these neogene and quaternary sediments and rocks has been carried out by Verbeek & Fennema (165), Mohr (111), Rutten (140) and others.

The first authors found andesitic material in various marls and limestones in Solo, in Soerabaia and Madoera.

Mohr on the other hand reports that in the limestones and marls of north Middle Java there is quartz sand with zircon and tourmaline, while he considers an admixture of volcanic sand of subordinate importance.

Rutten, after a systematic examination of 110 rock samples from the Java neogene, states that it contains much old-clastic material, especially dusty quartz, besides a little orthoclase, biotite, muscovite, zircon, tourmaline, microcline, andalusite, epidote and seldom plagioclase, augite and hornblende. This material of acid igneous rocks decreases on the island of Java, from north to south, both in quantity and grain-size, according to Rutten, it must therefore have been brought from the north. Towards the close of the neogene, volcanic activity increased, occurring earlier in the south than in the north. He reports from the basin of the Solo river and from Madoera, both richly quartz-bearing rocks and younger rocks, which contain much detritus of andesitic material.

Sediment 25, 35 cm thick, should be considered as a deposit of Solo river mud.

Sediment 26, as said above, contains minerals which are not found in sediment 25, moreover the quartz content, both relatively and absolutely, is higher than in 25. St. 26 lies much further from the Solo river mouth than 25, it is therefore highly improbable that actinolite, glaucophane, rutile, anatase and chromite would not be found in sediment 25, if they had been brought from Java. Thus it is probable that the 43 cm thick sediment 26 must be regarded, at any rate in part, as submerged „Soenda-land" upon which the silt of the Solo river has been deposited. The correspondence, both in nature and mutual ratios, between the basic plagioclase, the pyroxenes and the hornblende of the two samples confirms the idea that silt from the Solo river reaches St. 26.

The occurrence of glaucophane, so far as I know, is only reported from Java by Loos (102) in a black clay from Pati (res. Semarang), by van Baren (5) in a few soils derived from limestone in Middle Java, by Harloff (66) who found in the pre-tertiary of Loh Oelo amongst other things glaucophanites and glaucophane „garbenschiefers", and by Druif (43) in material from the old mud-wells of Poeloengan and Karanganjar (Soerabaia), which he believes to be derived from the „Soenda-land". Amphibole- and glaucophane-schists are known as solid rocks on Borneo from the crystalline schists regions of the Bobaris-Meratoes mountains and the Semitau-Sebilit region (Rutten, bibl. 142), so that the local appearance of minerals such as actinolite and glaucophane in the „Soenda-land" is comprehensible.

All this seems to intimate that the rate of settling in the most easterly part of the Java sea is low (at Sts. 26, 28 and 29) as compared to the rate of settling of the sediments in the deep basins of the Eastern Indian Archipelago.

The sample of this group which follows in table 18, sample 210, was raised at 20 km distance from the coast of S.W. Boeroe. Only 5 km from the coast close by where the Wai Koema flows into the sea, at St. 211, only rounded gravel and some fragments of shells (photo 4) were raised. This, as at St. 252 (photo 3), demonstrates strong currents along the south coast of Boeroe. At St. 210 a lower, but still considerable current velocity shows its effect, as the 57 cm thick sediment on this spot contains very little clay, as shown in fig. 20. The sample consists chiefly of sand of 500—20 μ diameter, with a peak at fraction 100—50 μ.

The mineralogical composition of sample 210 in table 18 shows that rock particles form about 35% of the sediment; they contain as recognisable components mica-schists, phyllites and siliceous rocks, and are mostly much weathered. Beside quartz quartzite is found in this sample; albite is present in the acid plagioclase. The monoclinic pyroxene is for the greater half pleochroitic from yellowish green to pale grey-blue green, the smaller part is titaniferous augite, pleochroitic from dull brown to purple, its presence probable indicates an admixture of detritus of alkali rocks. The zircon is colourless or pale pink, often handsomly idiomorphic, this mineral together with the augite, pre-

dominates in the „heavy minerals". The epidote is often greatly rounded. The anatase is yellow and shows marked striae. A part of the Foraminifera are not of recent habitus, they are much rounded and filled with calcite, they are probably derived from limestone. Coral particles are probably present, but are not clearly distinguishable.

This material shows much resemblance to the tertiary rocks, which, according to Wanner (174) surround the alluvium of the Wai Koema in a wide arc and in which he found limestone with corals, Echinoderms, Molluscs etc. Wanner gives this region as pliocene, he describes it as consisting of sandstones, conglomerates rich in quartzite and crystalline schists, and of breccia of sand, carbonate and coral rock. Eruptive rocks occurring in the tertiary are mica-andesites and possibly a few alkali rocks (leucitite, melilith-basalt and limburgite).

No particulars are known to me of the source of the Wai Koema.

Sediment 210 must therefore be regarded as material brought down by the Wai Koema and by neighbouring rivulets, which is later selected according to grain-size by the currents, changing in strength with the distance from the coast, the coarser particles and stones being deposited near the coast (St. 211) and most of the sand further off (St. 210) and the finer fractions further still.

Although samples 210 and 251, near south Boeroe, differ greatly quantitatively in mineralogical composition, they have in common titaniferous augite, anatase and staurolite.

The rest of the samples containing more or less terrigenous material of group IV come from the Ceram-Timor outer arc.

Near the east coast of Ceram the rate of supply of terrigenous components is low, as shown by the fact that only 5 km from the shore, to the east of Boela at St. 87, Globigerina Ooze is formed and that 30 km from the coast at St. 88 the Globigerina Ooze consists for no more than $^1/_4$ of terrigenous material. The high content of glauconite in both samples is also an indication of very limited transport of terrigenous material to these stations. The terrigenous material at St. 87 is composed of sand and clay (fig. 24 and table 18), sample 88 contains only 1% fine sandy minerals of 100—20 μ (fig. 24 and table 22).

The terrigenous components of sediment 87, according to the mineralogical composition, should be regarded as detritus of quartz-sandstones, lime-sandstones and a very little basic eruptive rocks.

According to Verbeek (168) the place Boela lies in an extensive plain of alluvial and quarternary material. In the small river Soeat which flows into the sea by Boela, he found boulders of lime-bearing sandstone, composed of granite particles (quartz, felspar, muscovite, altered biotite, zircon, iron ore and iron hydroxides) in a calcite matrix and of hard compact fossil-bearing limestone which contained pieces of quartz and iron ore.

According to Wanner (172) these rocks belong to the upper triassic rocks in flysch facies, widely spread in East Ceram, in which quartz-sandstones, mica rich sandstones and marls form a part. Locally basic eruptive rocks and radiolarites also occur. According to Verbeek (168), Rutten (136) and Brouwer (14) neogene and quaternary limestones and reef-limestones, claystones, marls and conglomerates are also found in East Ceram.

The terrigenous components of Globigerina Ooze 87 may therefore be regarded as detritus from Ceram's east coast.

The terrigenous components of sediment 88 (table 22) are not to be brought under group IV according to the definition; much cannot be said of their origin, it may be partly derived from East Ceram, partly from elsewhere.

In samples 87 and 88 and in some of the other samples from the Ceram-Timor outer arc an unknown secondary mineral appears, which is signified by „X". This mineral is further discussed in Chap. VIII.

At St. 91, lying on the east side of the Ceram sea by the shelf of the Vogelkop opposite to the Mac Cluer gulf, also Globigerina Ooze rich in glauconite has been deposited. The terrigenous components of this sample consist practically entirely of particles smaller than 100 μ (fig. 24 and table 22) from which rock particles are absent. This absence of rock particles, as in all other sediments of the Ceram-Timor outer arc of group IV, is due to the fact that the terrigenous material of the deposits consists chiefly of detritus of clastic sediments. As regards sample 91 the material (table

18) may have been brought by the many rivers which open on the south coast of the Vogelkop, and possibly the smaller streams which flow into the Mac Cluer gulf on the north coast of the peninsular of Bomberai. The basins of these rivers on the Vogelkop to a great extent and on Bomberai completely, lie in neogene formations (see the geological maps page XIII by Zwierzycki (194). These neogene formations, with the exception of the limestone mountains on the peninsular of Onin, are separated from the coast by more or less wide, marshy alluvial strips of land. According to Zwierzycki (192, 194) the neogene lies transgressive on the older formations. The oldest strata consist of conglomerates and breccia, composed by blocks of the underlying older rock with intercalated calcareous strata, or of limestones and Globigerina marls. Above this follows a thick flysch-like series of stratified (mostly quartz-) sandstones, claystones and marls in which local strata of browncoal occur. In the region around the Amaroe lake the youngest neogene deposits seem to consist of laminated lime and Globigerina marls, as is the case on the peninsular of Onin and in the Koemawa mountains.

In the rivers of West Bomberai boulders of older rocks are found; Zwierzycki (194) mentions boulders of granite and gneiss in the Wawije river, Loth (103) found quartzite in the A. Wos; this indicates the presence of granite and crystalline schists underneath the limestone mountains.

Some of the larger rivers of the Vogelkop in their upper course flow through crystalline schists, granite, serpentine, andesite and jurassic clay slates and glance slates, alternating with quartz-sandstones and compact limestones. The crystalline schists and gneisses are of great variety (see bibl. 194); at their contacts with granite they are altered contactmetamorphically.

The finer terrigenous material that reaches St. 91, brought by the rivers and through the Mac Cluer gulf, will therefore be chiefly detritus of neogene quartz sandstones, calcareous sandstones, claystones and marls, mixed in a less degree with detritus of older rocks. The limestones and calcareous sandstones from this area, where they contain terrigenous material, according to researches by Rutten (138) this consists principally of quartz splinters and sometimes also chlorite and serpentine; in one case acid plagioclase, orthoclase and perthite were found as well as quartz.

The presence of detritus of some older rocks in sediment 91 was indicated by basic plagioclase, highly pleochroitic hypersthene, actinolite, staurolite and chromite.

The mineralogical composition of sediments 324, 96, 95 and 97 shows a great resemblance to 91, although staurolite is absent in these samples, while 324 and 95 are distinguished by a very small content of heavy minerals (table 18). This remarkable resemblance in mineralogical composition may be traced to the similar petrographic composition of the neogene sediments of the southern part of the Vogelkop and of Bomberai. Zwierzycki (194) has already pointed out the stratigraphic resemblance between these two areas.

In sample 96, raised close by the coast at 850 m depth, limestone detritus in the form of calcite and fine aggregated calcite (smaller than 100 μ) was found; this is undoubtedly derived from the Koemawa mountains mentioned above, which stretch to the coast. These limestone particles cause the peak in the fraction 50—20 μ in the mechanical diagram of sediment 96 (fig. 20). The limestone particles should be regarded as terrigenous detritus, so that sample 96 is classified amongst the Terrigenous Muds, although the lime content is more than 30%.

Sediments 324 and 95 lie in the deepest part of the narrow trough which forms the southern extremity of the Ceram sea. As fig. 20 shows they are very fine-grained sediments, which collect in the deeper part of the trough, obviously the sandy particles are deposited near to the coast, which may be an indication that the material from Bomberai is carried away at a slow pace and that by this coast there is no effect of currents.

Sediment 97 lying on the west side of the Aroe basin is also fine-grained. The resemblance in mineralogical composition between samples 96 and 97 seems to indicate that this last sediment is a denudation product of neogene sediments from Bomberai also.

Between the Watoebela islands and St. 95 three Globigerina Oozes were sampled at stations 92, 93 and 94. The composition may be found in table 22 by the Globigerina Oozes. The content of terrigenous components larger than 20 μ of samples 93 and 94 is so small that a classification of them in any of the groups would be merely arbitrary. The minerals of sediment 92, immediately east of the islets of Poeloe Teor and Poeloe Baan, point to both crystalline schists and basic and ultrabasic rock as parent rocks of this material. This is in agreement with the rocks found by Ver-

beek (168) and by Brouwer (22) on the 350 m high Teor, namely mica-schist (sometimes with garnet, epidote and andalusite), phyllite, muscovite-gneiss, quartzite, crystalline limestone, quartz-sandstone, peridotite and serpentine, plagioclase-augite- and plagioclase-hornblende-rocks. The islet of Baan, according to Verbeek (168), consists of coral rock. The Globigerina Ooze 92 at 20 km distance from Teor contains thus detritus derived from that island with a grain-size of 200 μ and smaller. The terrigenous material of sediments 93 and 94, at 50 and 70 km distance from Teor, is at most of 100 and 50 μ diameter respectively. The terrigenous admixture in these Globigerina Oozes may therefore partly be regarded as denudation products from Teor, considering the corresponding habitus of the pyroxenes and hornblendes in all three samples and the predominance of pyroxenes in the heavy minerals. The rhombic pyroxene of these samples is both little decomposed and highly pleochroitic hypersthene and greatly affected bronzite. Further staurolite and andalusite occur both in 92 and 93. Calcareous debris is present in 92, and to a less degree in 93. There is thus a decreasing content of similar terrigenous material from 92 to 94 in these three Globigerina Oozes.

From the examination of the samples from the southern Ceram sea it appears that the material of the shores of this sea, both from the east and west side, has been little distributed. On the west side the material is deposited principally in a strip which stretches out for about 25 km from the coast. Most of the detritus from the Vogelkop and Bomberai on the east coast reaches the narrow trough of the southern Ceram sea. Between this trough and the western strip of coast very little and very fine terrigenous material is deposited (St. 88, 93 and 94).

Sediment 104 lies in the middle of the deep part of the Aroe basin. The sample represents an upper layer of 62 cm, which, like sediment 362 in the Weber deep (p. 141) is remarkable for its mechanical composition (fig. 20). The sediment consists for the most part of fine sand, while usually in the deeper basins it is the smallest particles that are deposited, except in the cases where recent-volcanic ash has been brought. There are two possible explanations of this. One is that we have here a relict bottom of terrigenous sandstone. But this seems impossible as the great troughs serve as collectors of all the settling material and there is no reason why the Aroe basin should form an exception to this rule. The basin covers an area of 11.000 square kilometers at a depth of more than 3000 m while the sills of the basin lie much higher, at 1600 m and 1480 m depth (cf. van Riel bibl. 130), so that the presence of very strong bottom currents which entirely prevent the settling of terrigenous material, is highly improbable.

The alternative is that sediment 104 is derived from precipitated material, either of submarine or terrigenous origin. Verbeek (168) in his researches on the island of Great Kei came to the conclusion that a portion of the northern and middle part of the eastside of the island has sunk away. He reports the steep E. coast to consist of eocene marly laminated lime. Brouwer (22) found moreover calcareous marls, mica-sandstones, soft slates and hornstone-bearing limestones in this formation. Locally on the coast Verbeek observed that the marl-strata were undermined by the breakers, which caused a crumbling away of the coast.

Zwierzycki (194) reports similar continuous steep limestone mountains, which reach a height of more than 1000 m. from the south coast of New Guinea between the Argoeni and the Etna bays.

Moerman (193) met with mica- and chlorite-bearing quartz-sandstones likewise in this eocene formation.

St. 104 is at about the same distance from the coast of New Guinea as from Great Kei.

The mineralogical composition of sediment 104 (and of 103) is distinguished from the other samples of the Aroe basin by a higher muscovite content and by the heavy minerals being chiefly green hornblende and zircon with very few pyroxenes, epidote and tourmaline. This simple composition also indicates a local place of origin for the sediment: the place, however, cannot be determined only from the correspondence in mineralogical composition of samples 104 and 103.

At St. 102, only 2 km from the coast of Great Kei, a very coarse-grained sediment was raised (fig. 20) which can be clearly recognised as marl-detritus. The sample consists of fully 45% of particles larger than 2 mm; most of these are pieces of marl, which is sometimes clearly stratified, and further a few molluscs, bryozoa and coral fragments. In the fractions smaller than 2 mm calcareous aggregates and calcite form the chief components. Beside recent Foraminifera in fractions 100—50 μ Globigerinidae, Rotalidae and Textularidae or Buliminidae with old habitus occur.

They are rounded and entirely filled with calcite. This shows that we here have calcareous organisms from limestone, in a secondary finding place. The sediment is therefore regarded as detritus of terrigenous material and in spite of its high lime content it is classified with the terrigenous sediments. The content of recent Foraminifera in sample 102 amounts to some 10%. The mineral content is low and the content of heavy minerals very low. Probably the mineral combination of sample 102 represents that of the marly limestone of the neighbouring coast of Great Kei.

Brouwer has described from that part of Great Kei which extends from Ohilim to Vako, marly limestones and one marly slate which contain Foraminifera (Globigerinidae, Textularidae, Rotalidae and a few Nodosaria) and sponge spicules. The calcareous mass in these samples is partly clouded and partly clear calcite. Sediment 102 may thus be regarded as detritus of these marly limestones. The coast here slopes very steeply, continuing under the sea. The steep slope of the east coast, according to Verbeek (168) is connected with a shifting and sinking of the eastern wing, so that a portion of the coast now lies beneath the sea and which accounts for the small breadth of the island at Matahollat.

Sediments 101 and 100, lying 20 and 50 km from the coast of Great Kei, in contrast to 102, consist of very fine material, while such limestone detritus as there is, is also fine-grained like that in sample 104. In the southern part of the Aroe basin the finest material has collected in the normal way at the greatest depth. The mineral content of 101 is relatively a little higher than of 102, while the mineral content of 100 corresponds to that of 104. The mineral composition of 101 also corresponds mainly to 102, and the mineral composition of 100 to 104. At the same time a little material similar to 102 (derived from Great Kei) is mixed with 100 (titanite, rutile, brookite, anatase); while 101 contains some material that corresponds more to 104 (chromite, biotite).

Both the amount of sandy material and the grain-size of the sand are greater in 104 than in 100, both of which samples were raised in the deepest part of the Aroe basin. The origin of this sandy material should therefore be sought rather in the northern half of the Aroe basin.

On the east side of the Aroe basin, nearer to the Aroe islands at St. 98 a „trace" of Terrigenous Mud was raised and at St. 99 a small sample of Globigerina Ooze. St. 98 lies by the edge of the Sahoel shelf; St. 99 lies at 1900 m depth in the Aroe basin.

Sediment 98 contains only 10—15% lime, chiefly as Foraminifera, and much clay with a good deal of quartz, less plagioclase, and very little muscovite and chlorite (table 18). The glauconite content of 98 amounts to some 10% and pyrite about 5%.

Sediment 99 is a Globigerina Ooze with a good deal of clay and little sandy terrigenous material of about the same composition as that of sample 98. It contains little glauconite and sporadic aggregates of pyrite globules in the Foraminifera.

The fact that at St. 98 so little material has been deposited corresponds to the report by Zwierzycki (193) that the rivers of the Aroe islands carry off so little mud that the water around the islands remains quite clear and extensive coral reefs form in it; the high glauconite content of the sample, also, is accounted for by this. Kuenen (97) found coral reefs even far from the coast in the rivers in what he considered to be tidal channels. The low Aroe islands, with the Sahoel shelf form a part of the Australian continent, they are the continuation of the old gneiss and granite mass of Australia, which is here covered by neogene sediments. A proof of this is the presence of a granite hill on Poeloe Trangan and the frequent occurrence of quartz sand of granitic derivation and of quartzite in the neogene sediments of the Aroe islands, pointed out by Gregory (62) and Verbeek (168). The neogene of the Aroe islands consists of clay-, sand- and limestones.

The material of sediment 98 may be compared to the neogene sediments of the Aroe islands. Considering the relatively high quartz and pyrite content of this sample, it is more probable that it consists of material slided from the Sahoel shelf rather than brought by the rivers of the Aroe islands. At St. 99, besides what comes from the Sahoel shelf, very fine terrigenous material may have been transported from elsewhere.

South of the Aroe basin lies St. 105 in the vicinity of the Tenimber islands on the sub-marine ridge which connects the Kei and Tenimber islands. St. 110 lies on this ridge close in the Tenimber islands. St. 109 is situated in about the deepest part of the Arafoera sea. Stations 107, 108 and 106 lie in the part of the Arafoera sea which slopes towards the Sahoel shelf.

At stations 105, 108, 109 and 110 Globigerina Ooze was sampled in layers which vary in thick-

ness from 34 to 62 cm, at St. 107 the amount of Globigerina Ooze is marked as „large". In the 42 cm thick sediment 106 a stratum of Globigerina Ooze 106B lying upon a stratum of Terrigenous Mud 106A are distinguished.

The content of sandy minerals in all these samples is low; it is highest in sample 107 lying far from the Tenimber islands; the content is higher in the lower stratum 106A than in 106B; of the other samples the sandy mineral content of sample 110 lying close to the coast of Jamdena is somewhat higher than in the rest.

The mineralogical composition of samples 110 and 105 show a great resemblance, while that of samples 109 and 108 only deviate from these in containing biotite, some more muscovite, and actinolite, and in 108 moreover titanite. Further the content of pyroxenes and hornblendes in 109 and 108 is relatively higher than in 110, but this is of little quantitative importance, as the heavy mineral content of the samples is particularly low. A relatively and absolutely higher pyroxene content is shown in sediment 111 (of group III).

The terrigenous material of samples 110 and 105 is probably entirely, and that of samples 109 and 108 principally, derived from the tertiary Globigerina marls and limestones, which, according to researches by Verbeek (168) and Brouwer (21) occur on the east coast of the Tenimber islands. Sediments 109 and 108 may moreover contain some material derived from the Australian continent.

As the content of fine sandy material (100—20 μ) in sample 107, on the east side of the arc, is considerably higher than that of the other samples, this terrigenous material cannot be derived from the Tenimber islands, but must come from the Australian continent. Probably it is river mud from the large rivers, there may also be material carried from the Sahoel shelf.

At St. 106 there lies a typical coarse-grained Globigerina Ooze upon a very fine-grained Terrigenous Mud. The sharp contrast in mechanical composition of these two sediments comes out very clearly in fig. 24. Moreover the lower stratum is distinguished from the upper one by a higher content of pyrite and a higher content of fine sandy minerals (chiefly 50—20 μ). As appears from the small content of terrigenous material of the upper stratum 106B, St. 106 with St. 98 belong to the region of slow sedimentation surrounding the Aroe islands. The terrigenous material of this upper layer might come either from the Tenimber islands, the Aroe islands or the Sahoel shelf. The bottom layer, 106A, has the lowest content of heavy minerals of all the samples from the Arafoera sea. A further research as to the distribution of the bottom layer of Terrigenous Mud will be needed to show whether we here have slided off material from the Sahoel shelf or whether the sedimentation conditions have been greatly changed at this spot.

The Terrigenous Mud 114, sampled to the south west of the island of Babar, belongs to the more muscovite-bearing sediments of this group, moreover there is some material in it which belongs to group IIIb.

The mechanical composition of sample 114 (fig. 20) shows that here medium to fine-grained material is deposited. According to its mineralogical composition (table 18) it should be regarded as detritus of rocks of the island of Babar.

The researches of Verbeek (168) and Oyens (104) have demonstrated that the chief formation of Babar consists of claystones, sandstones and limestones. Around the island are various raised young coral reef terraces, which however, are broken through in many places by the rivers. In the rivers most of the boulders consist of sandstone, limestone, marls, claystone, clay iron stone and concretions, which sometimes contain ammonites and eruptive rocks. The sandstones of the western part are mica-bearing (upper Trias); the limestones and claystones also contain quartz and sometimes muscovite. The eruptive rocks are diabases and diabase tuffs. Locally quartz porphyry, porphyrite, granite and peridotite altered into serpentine are found.

The minerals in sample 114 correspond in general with the mica-bearing sandstones. There is little material of altered diabase and peridotite (chromite); and further a certain amount of limestone particles, as shown by the occurrence of calcite in the fractions 100—20 μ (table 18), while the finer fractions also contain carbonate. The occurrence of titaniferous augite (beside pale green and strongly affected augite) and of glaucophane in sediment 114 may be a sign of the presence of more rock species on Babar, than have been mentioned above.

V. Terrigenous Muds, which consist chiefly of detritus from basic old-volcanic rocks

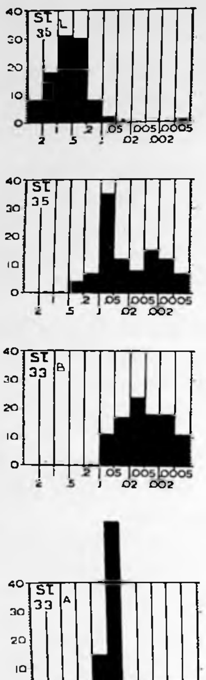


Fig. 21. Mechanical Analyses of Terrigenous Muds, derived principally from alkali rocks.

a. *Sediments which are derived from detritus of alkali rocks*

These Terrigenous Muds lie in the southern part of the Makassar Strait and east of the island of Saleyer.

The mineralogical composition of these samples is given in table 19, the mechanical analyses are graphically represented in fig. 21.

The coarse sandy sediment 35^{L} (photo 6), which is deposited in the bay of Mamoedjoe, proves to contain only detritus of alkali rocks with some organisms and organic matter. The material is only partially altered and can therefore be well recognised. It is composed of a great many pale grey to green rock particles, of augite, with less sanidine, leucite, biotite, apatite and iron ore and a very little green hornblende. The same minerals can be distinguished in the rock particles, some of which have a yellowish brown weathered surface.

The augite is found as: 1. green, practically non-pleochroitic augite, 2. pleochroitic from yellow to green or yellowish green to faint grey-blue, 3. almost colourless and sometimes unevenly coloured augite.

The leucite is usually not isotropic, sometimes it shows striae and twin lamellae, in a few specimens zoning was observed; the leucite is occasionally isotropic and then of a dull white.

The sanidine is usually translucent, a few showing zoning. There are rare inclusions of augite, biotite and iron ore. In the fractions 100—50 μ the sanidine sometimes bears inclusions of green hornblende.

The biotite is brown or reddish brown, moderately pleochroitic, sometimes of green colour; it is partly idiomorphic, some show worn edges.

The apatite appears as fine, clear, sometimes elongated prisms, but is also found as short, thick columns containing much dust.

The derivation of the material of sediment 35^{L} must be looked for in the neighbourhood of the bay of Mamoedjoe. Carthaus (34) has reported the presence of leucite rocks from this neighbourhood; he observed at the same time a lively green shore sand near the village of Mamoedjoe.

Bücking (29) has described the rocks collected by Hoven during the expedition of H.M. Surveying Vessel „Makassar" along the west coast of Celebes. Amongst these were leucitite, leucite-trachyte and trachyte in a conglomerate collected near the village of Tambi, east of the village of Mamoedjoe on the bay of Mamoedjoe. The finding place lies some 300 m from the coast, at the foot of a hill. The grey-green leucitite contains biotite, pale augite, magnetite and a little leucite. The grey-brown leucite-trachyte impregnated with brown iron contains many altered leucite-phenocrysts, greenish yellow augite and magnetite; the ground-mass consisted of a fabric of many sanidine laths with augite and green or brown decomposition products. The light grey trachyte contains fresh sanidine crystals up to 18 mm in size, which usually formed Carlsbad twins and often had a fine zonal structure; the ground-mass consisted of sanidine laths and decomposition products amongst which brown iron and chlorite were demonstrated. The alteration products also form pseudomorphoses, according to Bücking probably after hornblende.

Gisolf (59) has described boulders collected by Abendanon in the S. Mamoedjoe, as leucitites and shonkinite.

The latter consisted of leucite, nefeline, titaniferous augite, amphibole, plagioclase and green aegirine-augite. The components of the shonkinite, however, do not form part of sample 35^{L}.

The presence of large sanidine crystals in sediment 35^L indicates that besides leucitite and leucite-trachyte, trachyte forms the parent material of this sediment.

The high augite content of the sample is probably due to the selection according to weight exercised by the breakers on the coast upon the material. On the north coast of Java a similar selection was observed by the present author in andesitic material; the pyroxenes and iron ore proved to predominate greatly over the plagioclase and volcanic glass in the shore deposits, in contrast to the ratio shown in the same andesitic material of the soils deposited by rivers behind the coast and in which the light minerals predominated, as this is the case with the andesitic ash.

Sediment 35^L is probably the product of coastal erosion. The material of this sample, compared to the rocks in the surrounding areas described by Bücking and others, is not much decomposed.

Detritus of alkali rocks form the chief components of samples 35 and 33A raised in the Makassar Strait, it is found in smaller quantities in the Globigerina Ooze 34 and little in the Terrigenous Mud 30.

The minerals derived from alkali rocks in the sediments 35 and 33A are of the same habitus as those in sample 35^L. The sanidine, however, occurs chiefly as laths. The minerals are more decomposed in these samples than in 35^L. The leucite is for a great part decomposed; it is rounded, usually isotropic and its refractive index is usually less than 1.50 and thus lower than in fresh leucite. The leucite may be translucent or cloudy, it is usually altered into analcite.

The rock particles are grey to green, the latter especially, have been greatly decomposed, they contain much chloritic matter.

The basic plagioclase is partially of zonal structure.

The monoclinic pyroxene is very faintly pleochroitic and greatly decomposed, showing many ragged ends.

The prismatic green hornblende is pleochroitic from yellowish green to green, in sample 30 only, there is also fibrous green hornblende.

The two samples 35 and 33A represent the lower layers in the sediments of 38—78 cm and 15—20 cm depth respectively. The mechanical composition of these two strata with the peak in fraction 100—50 μ greatly resembles that of volcanic ashes (fig. 21). Kuenen's description indicates (table 2) that the tuff stratum occurs in 33 at 6—27 cm; a few mm plant remains are followed at 27—30 cm depth by coarse grain. This striking amount of organic matter occurs in the form of brown to black plant remains. It is also found in samples 35 and 35^L, while it is almost entirely absent in samples 30 and 31, which lie nearer to Borneo. The greater amount of plant remains in the lower strata of 35 and 33 might indicate that these strata are composed of precipitated material from the west coast of Celebes; the homogenity of the material (chiefly tuffs of alkali rocks) also points to this origin.

The two layers differ little in mineralogical composition, 33A has a higher content of biotite, sanidine and plagioclase than 35, and also contains some volcanic glass in contrast to 35.

From the coast of Mandar, near which St. 35 lies, Bücking (29) has described a large number of rock samples collected by Hoven. He found here principally leucite and andesite rocks, limestone and coral rock occur in much smaller quantities. From cape Ongkona northwards leucite-rocks and -tuffs predominate, south of the cape andesite-conglomerates and -tuffs are in the majority.

The leucite rocks were leucite-basalt and leucite-trachyte; in the leucite-tuffs beside these rocks lapilli of leucitite were found as well.

Near cape Perasangang biotite-andesite and augite-andesite-tuff were found.

The boulders of the Kali Maloeno collected at cape Onang all belonged to the same sort of leucite- and andesite-tuffs and -rocks; a few enstatite-andesites and a brown hornblende-bearing granitite were found.

The mineralogical composition of sample 35 corresponds in general to the leucite tuffs of the Mandar coast. a certain amount of andesitic material is probably included; in subordinate quantities there are some minerals in 35 (plagioclase II, quartz, actinolite, muscovite, zircon, tourmaline and garnet) which are widely distributed in the sediments more to the north in the Makassar Strait.

Sample 33A contains evidently more biotite-andesitic and leucite-tefritic material than 35. Gisolf (59) found leucite-tefrite as solid rock and as boulders in the Saädang river.

The smaller content of detritus of corresponding alkali rocks in the Globigerina Ooze 34 and

TABLE 19. Mineralogical Composition of Terrigenous Muds-

No.	Fr.	rock particles	plagioclase I	plagioclase II	sanidine	leucite and analcite	quartz	volcanic glass	augite	enstatite	olivine	green hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	zircon	tourmaline	garnet	magnetite and ilmenite	pyrite	glauconite
35L	1	75			3	1			2							4										
	2	81			4	3			6							3		1								
	3	55			5	3			34			0,1				1		1						0,3		
	4	30			5	4			50			0,1				2		1,5	2					5		
	5	35			9	10			24							3		3	3					11	1	
	6																								0,5	
35	1																									
	2															6	4									
	3		0,3						tr.							16	2									
	4	32	5		1	6	tr.		1							10	1									tr.
	5	25	8	6	3	4	3		6	1	tr.	0,5		0,5		4	tr.	3	0,5	0,3	tr.	tr.		3	1	1
	6																								1	
34	5	3	5	12	1		6	1	2	0,5		0,5		0,5	0,1	0,5	tr.	1	0,4	0,3	0,2		tr.	0,5	1	0,3
33A	1							3								14										
	2							3								40										
	3	3	0,5		2			4								45									0,5	
	4	35	8	3	6	2	1	3	2	tr.						27	0,1								1	
	5	35	15	7	10	1	3	1	7	0,2		2	tr.	0,3		4	1	1	0,3	0,1	tr.	tr.	tr.	2	3	
	6																								6	
30	2		2																							
	3																									
	4		0,5	0,3			0,2	tr.								0,5	0,3									
	5		1	3	0,1		3	1	0,4	tr.		0,1	tr.	tr.		0,2				tr.	tr.			0,1	tr.	
	6																								2	
186	1																									
	2																									
	3	1			0,2				0,2																	
	4	25	0,1		1	1			2							tr.										
	5	5	1		5	0,5		tr.	4			1						tr.	tr.					1		
	6																									
187	2																									
	3							0,5																		
	4																								tr.	
	5	0,5	1	1	0,3		tr.	1	0,7			0,5	tr.	tr.		tr.	tr.			tr.				0,3	0,5	
	6																								2	

the Terrigenous Mud 30, which lie nearer to Borneo, make it probable that this material also is derived from the west coast of Celebes.

Sample 33B was not received. The mechanical diagram of this 0—6 cm thick upper layer corresponds to that of sediment 30.

The Globigerina Ooze 185, lying south west of Southern Celebes, contains only 5% of minerals. These minerals bear a great resemblance to those in the preceeding samples; they are pale green, green or from yellow to green pleochroitic augite, with less plagioclase, sanidine, highly pleochroitic dark brown or red-brown, often idiomorphic biotite, red hornblende and brown volcanic glass. Leucite was not demonstrated, but a little analcite. It is therefore not quite certain that this material (table 25) is derived from alkali rocks; the corresponding habitus of the minerals in sediments 185, 33A and 35 make it probable, however.

The origin of the terrigenous components of this sample, 185, cannot be given. No rocks are known to me from the south west point of the southern arm of Celebes, nor from the Panggowa mountains. The Sarasins have described limestone hills covered by volcanic tuffs near the bay of Laikang. They consider these tuffs to be derived from the Peak of Bonthain, as near Allu they found a boulder of olivine-rich basalt. St. 185 apparently does not lie in the distribution region of the Peak of Bonthain, as according to the Sarasins the mountain is chiefly built up of basalt and augite-andesite, while Wichmann also found a hornblende-andesite.

derived principally from alkali rocks.

limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echini spines	Lamellibranch fragments	Pteropods	Gastropods	otoliths of fish	Alcyonarian spicules	calcareous Sponges	calcite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
		85		3		2								3	8					7	19,8
		98		0,5										0,5	1					1	33,6
		99,4												0,6	0,6						32,6
		99,6												0,4	0,4						9,3
		99												0,5	0,5		tr.		tr.	0,5	1,8
		96													1	1	tr.		1	2	0,5
															†					†	0,04
	1	11	52	1										2	55	2			2	32	0,2
	3	21,3	66	1	1									1,5	69,5	6	tr.		6	3	3,8
tr.	5	61	34	1	0,5									1,5	37	1	tr.		1	1	6,9
tr.	3	73	21	1	0,3						0,3	0,2	0,6	1,5	24,9	2			2	0,1	34,8
	6	59									0,5	0,2			37	3	tr.		3	1	12,4
0,2	2	38	--37----		0,5		1			0,5	3		2	17	61	1			1		12,1
		18			2										2					80	0,8
		43	0,5		0,5										1					56	2,0
		55	20	3											23					22	2,7
		88,1	9	1,8	tr.										10,8		0,1		0,1	1	15,2
		93	---5----		0,2								0,3		5,5	0,3	0,2		0,5	1	61,0
		89,5									0,1				5	2	0,5		2,5	3	4,7
	95	97	3												3						0,2
	92	92	7	tr.										1	8						0,7
0,2	94	96	---3,8--											0,2	4	tr.	tr.		tr.		4,7
0,5	77	86,5	--11----		0,2									0,3	11,5	2			2	tr.	6,9
	45	79									1				13,5	7	0,5		7,5	tr.	17,8
			†	†				†	†					†[1])							0,2
			92	3		1		1						2	99	1			1		2,7
	1	2,4	73	2	1		3	1						12	92	5	0,3		5,3	0,3	8,0
	0,3	29,4	--25----		0,5		2	1		1	0,5			38,5	68,5	1	1		2	0,1	15,5
	0,4	18	--16,7 --		0,2		1			0,5	7			53	78,4	3	0,3		3,3	0,3	25,2
	1	13									5				80,4	5	1	0,1	6,1	0,5	13,2
	3	3	96											1	97						0,2
	12	12,5	87	0,5											87,5						0,3
	40	40	44	1			1							1	47	2	10		12	1	2,2
0,1	6	12	--45----		0,1		0,5			0,4	7		3	22	78	8,5	1		9,5	0,5	5,6
	2	8									5				75	13	3	0,5	16,5	0,5	17,1

Sediments east of Saleijer.

In sample 186, raised only 2 km from the coast of Saleyer at 1400 m depth, sanidine and augite are the most prominent minerals (table 19), together with a smaller amount of plagioclase, analcite, green hornblende, iron ore, and traces of biotite, apatite and volcanic glass. The sanidine laths are partially cloudy. The analcite is practically isotropic and shows no distinct crystal faces. The augite is pale green, green or pale yellowish green. The plagioclase, to judge by the refractive index, is labrador-andesine. The biotite is yellowish brown and greatly decomposed.

This material is probably derived from alkali rocks. It is distinguished from the samples from the Makassar Strait by the practical absence of biotite.

The mechanical diagram of 186 in fig. 21 shows peaks in fractions 100—50 μ and 5—2 μ; the first peak is caused by the high lime-content of fraction 100—50 μ, this is detritus of calcareous banks and coral reefs; the minerals occur in the same quantities in fractions 200—100 μ and 100—50 μ.

The derivation of sediment 186 must be sought on Saleyer. Verbeek who has examined this island records in his Molukken report (p. 39) that the east coast has numerous white lime walls, the remains of former reef limestones, which have slid down the steep slope through the crumbling and washing away of the underlying soft sand- and claystones.

The island proved to be built up of strata of sandstones, breccias, claystones and marls dipping westwards, upon which young limestones and coral rocks have been deposited discordantly. The island has therefore been greatly raised during the quaternary period. East of Saleyer the sea-floor declines very steeply.

[1]) a.o. Corals and Balanus.

Wichmann (183) has described boulders from Saleyer collected by Weber and Verbeek (168) described sandstones and breccia from the island. They were augite-, hornblende- and biotite-andesites and hauyn-bearing nefeline-tefrite, in which leucite is absent and sanidine could not be shown with certainty. This tefrite was found on a path between Gantaroeng and Saleyer. No samples have been collected from the region near by St. 186. As the sediment at St. 186, considering the high content of calcareous particles would seem to consist partly of material transported or precipitated from the east coast of Saleyer, it is probable that on the island more species of alkali rocks occur than those which Verbeek found.

Sample 186, besides material from Saleyer, contains some 30% calcareous and siliceous organisms of which 18% are pelagic Foraminifera. Although the lime content of this sediment amounts to 52.6% it is classified amongst the Terrigenous Muds, as more than half of the lime is derived from the land as calcareous debri.

Sample 187, raised further from the coast of Saleyer, contains the same minerals as 186 and also calcareous debri, further traces of quartz, muscovite, actinolite and epidote were found in it. The mineral content of the sample is, however, only 1 to 2% and the size of the mineral and calcareous grains both lie below 50 μ. The diminution of grain-size in the same material with the distance from the coast of Saleyer is another indication that the terrigenous material of these samples is derived from that island. The mechanical diagram of 187 has peaks in the fractions 50—20 μ and 5—2 μ; the first peak is again due to the high lime content of the fraction. The content of pelagic Foraminifera in 187 is not more than 10%, other calcareous organisms occur in comparatively small quantities. This sediment is therefore taken to be a Terrigenous Mud also.

To the north east of St. 187 lies St. 200 on a ridge which forms the sub-marine connection between the southern arm of Celebes and the Tijger islands. In this sediment there is still a small amount of the same minerals as in 186 and 187, although the content of green hornblende is relatively higher in 200 (cf. table 19 and 25). Limestone detritus was not found in the fractions larger than 20 μ; this sample consists for more than 50% of pelagic Foraminifera, it belongs to the typical Globigerina Oozes. The small content of terrigenous components in the sediment may be derived partly from Saleyer and partly from other islands.

Finally the Coral Sand 199 contains a small amount of minerals which should be regarded as alkali rock detritus. The mineral preparation received from this station proved to consist half of rock particles; amongst the minerals there was most augite, yellow to green pleochroitic, with less plagioclase and small quantities of green hornblende, biotite, brown volcanic glass and analcite (table 26).

Verbeek (168) reports alkali rocks or breccia from the island of Tamboeloengan, to the south of Saleyer. A sample raised close to the southern point of this island, of leucite-tefrite rich in leucite, was composed of plagioclase, leucite, augite (yellowish green to bottle green), magnetite, apatite and clear brown glass. From the island of Poelasi, lying nearer to St. 199 Verbeek reports only augite-andesite.

The larger island of Tanah Djampea, lying S.E. of St. 199, according to Hetzel (75) is composed of alkali and calc-alkali rocks with a little reef limestone and limestone. The calc-alkali rocks occur particularly in the eastern part of the island and along the S.W. coast; the remaining part of the island seems to be chiefly occupied by alkali rocks (quartz-monzonite, nefeline-monzonite and aplitic nefeline-monzonite, and essexite).

The origin of the terrigenous components of sample 199 must be looked for on one of these islands.

b. *Sediments which consist of detritus of calc-alkali-rocks.*

In this group the detritus of calc-alkali rocks of all periods, from the oldest rocks known to the quaternary are included; only the recent-volcanic material of volcanoes active in historical times is included in the Volcanic Muds, which have been treated already.

These sediments occur in two large groups in the southwest and northeast of the eastern Indian Archipelago. In between they appear occasionally.

The mineralogical composition and the mechanical analyses of the samples raised in the southwest near the island of Soemba may be found in table 20 and fig. 22.

At St. 136 lying to the east of Soemba a Globigerina Ooze has been deposited which contains

practically no particles smaller than 20 μ (fig. 24), while the Terrigenous Muds 142 and 153, further from the coast of Soemba, have a high fraction 20—2 μ (fig. 22). Clearly the current at St. 136 is fairly strong, this Globigerina Ooze contains some 10% coarse sandy terrigenous material and practically no clay. The minerals of this sample must be derived from little altered basic volcanic parent rock: the plagioclase in it is often of zonal structure, the pyroxenes are common green augite and highly pleochroitic hypersthene, which are sometimes encrusted in volcanic glass. Moreover the sediment contains limestone detritus. The terrigenous components correspond, thus, to the composition of the east coast of Soemba.

Verbeek (168) reports East Soemba to be covered by a limestone terrace. Witkamp (185) found here, besides limestone with numerous Karst phenomena, Globigerina marls, and moreover igneous boulders in the rivers. The researches of Witkamp have shown in general that the neogene sediments of which Soemba consists for the most part, are largely made up of products of great volcanic eruptions (andesite, basalt, rhyolite), which took place in the tertiary period, in the form of tuff marls, tuff sandstones, conglomerates and breccia.

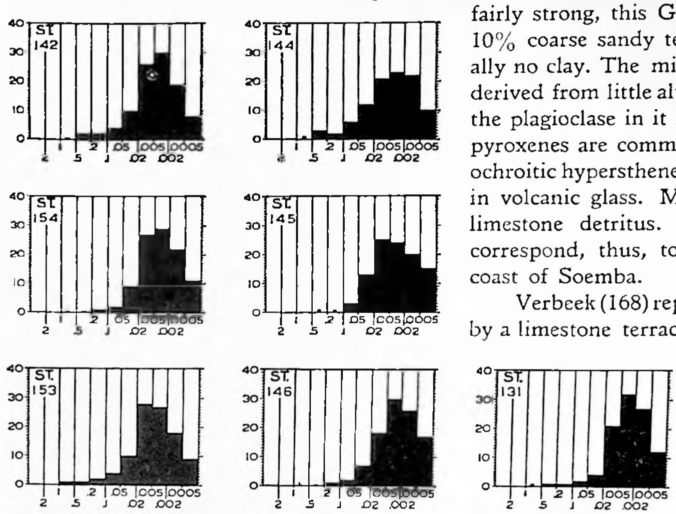


Fig. 22. Mechanical Analyses of Terrigenous Muds, derived principally from calc-alkali rocks.

It is the detritus of these volcanic products and of limestones which form the terrigenous admixture of the Globigerina Ooze 136. The finer detritus did not become deposited here owing to the rather strong current velocity.

In the Terrigenous Muds 142 and 153, lying at a greater distance from the shore and further from the Sawoe Straits, the finer material and the clay came to settle. Sediment 142 consists chiefly of little altered andesitic material with a relatively higher content of hypersthene than 136. No limestone detritus was detected in 142 and 153; this material was apparently mostly dissolved before reaching the greater depths. In sample 153, besides much andesite material there are constituents of other, older volcanic rocks, considering the presence in it of greatly affected rhombic pyroxene and colourless diopside; these minerals are also sporadically present in sample 142. Detritus of pre-neogene rocks may have been brought here by the Melolo river a.o., as according to Kemmerling (see bibl. 35) these pre-neogene rocks are represented in the Massoe mountains and the river basins connected with them in East Soemba. These rocks contain eocene limestones and marls, conglomerates and sandstones, as well as older volcanic rocks and contact-metamorphic sedimentary rocks. Verbeek reports from the Massoe mountains diabase porphyrite and diabase breccia. Roggeveen (134) has described in rocks collected by ten Kate and Witkamp various hornblende-diorites (including diopside-bearing), granodiorites and granite, porphyrites and a metasomatically altered rock, composed of quartz, muscovite, tourmaline and leucoxene.

The sediments near the south coast of East Soemba (143, 144, 145 and 146), in contrast to those from the east coast, contain a large amount of detritus of older basic to intermediate igneous rocks. The minerals to a great extent are strongly affected; the high epidote content is remarkable. In the acid plagioclase albite was observed in 144 and 145. The samples contain both translucent and dusty quartz.

As on the south coast of East Soemba the older rocks predominate and neogene sediments only occur subordinately, the terrigenous components of the Globigerina Ooze 143 and of the Terrigenous Mud 144 may be regarded as detritus from the south coast of East Soemba. This only partially applies to the Terrigenous Mud 145.

If the mechanical composition of samples 143, 144 and 145 (fig. 22 and 24) are compared,

TABLE 20. Mineralogical Composition of Terrigenous Muds of Group Vb

No.	Fr.	rock particles	plagioclase I	plagioclase II	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	green and brown hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite	apatite	epidote and zoisite	zircon	tourmaline	garnet	titanite
136	5	3	5	0,5	0,3		3	2	4		0,1						0,1		0,1				
142	2																						
	3	3					1																
	4	2	3				3		1														
	5	19	12	2	3		10	0,5	3,5		0,5				tr.			0,1	0,2	0,1			
	6																						
153	2						2																
	3	0,5					1																
	4	0,5	0,5		tr.		2																
	5	22	20	6	4		2	1	3		1,5	0,5			tr.		0,3		0,5				
	6																						
148	5	5	9	1	0,3		4	1,3	1		0,2				tr.								
137	5	1	8	tr.	tr.	tr.	1	tr.	0,2		tr.				tr.								
138	5	1	2	0,5	0,3	tr.	2	tr.	0,2		tr.					tr.			tr.				
154	2																						
	3			tr.	tr.																		
	4	1	0,2	0,2			1	tr.	tr.														
	5	1	4	3	1		2	0,1	0,2		0,1						0,1	tr.	0,1	tr.			
	6																						
143	5	9	7	6	1		12	0,5 (9)	0,8 (15)	tr. (½)	0,7 (14)				0,5	0,5	3	0,1 (2)	3 (58)	tr. (1)		tr. (0,2)	tr. (0,3)
144	2		1																				
	3	tr.					0,2								0,2	0,2							
	4		tr.	tr.			3								tr.								
	5	3	3	2	tr.		11	0,5 (20)	0,7 (28)	tr. (1)	0,2 (8)				tr.	tr.	tr.	tr. (1)	1 (40)	tr. (1)			tr. (1)
	6																						
145	5	3	7	25	6		13	1 (22)	1 (22)		0,6 (12)		0,4 (8)		3	8	1	0,2 (3)	1 (20)	0,1 (2)	0,1 (2)	0,5 (9)	tr. (tr.)
146	2																						
	3		0,2		0,5		22									tr.							
	4		0,5				28	tr.	tr.														
	5	2	9	5	1		50	1 (47)	0,5 (23)		0,1 (4)		0,1 (4)		tr.	0,2	0,2	0,1 (4)	0,3 (17)	tr. (0,5)		tr. (0,5)	
	6						25																
382C	5		0,5	0,3	0,2		2	0,3 (25)	0,1 (8)		0,1 (10)		tr. (5)				tr.		0,3 (28)	0,1 (12)	tr. (5)	tr. (2)	tr. (5)
382B	5		0,5	0,3	0,3		12	0,1 (16)	0,1 (16)		0,1 (11)	tr. (1)	tr. (5)	tr. (0,1)					0,2 (31)	0,1 (12)	tr. (2)	tr. (2)	
131	2																						
	3			tr.											0,5								
	4			1	0,5										0,1								
	5	0,5	2	1,5	1		4	0,1 (20)	0,1 (28)		tr. (6)		tr. (4)		0,1		tr.		tr. (9)	tr. (13)	tr. (9)		tr. (3)
	6																						
133	5	5	4	8	12	2	3	0,2	0,5		0,1		tr.			0,5	0,2		tr.	0,1	tr.		
162	P	†	†	†			†	†	†		†		†			†	†				†		
248	5	0,5	1,5	0,5	tr.		2	0,2 (33)	0,1 (22)		0,1 (17)		tr. (9)			0,5			0,1 (16)	tr. (2)			tr. (1)
206	5	0,1	0,5	0,2	0,1		tr.	tr.			0,1		0,1		tr.	tr.							

it will be seen in the first place that the strong currents in the Sawoe Straits are no more felt at St. 143 at 1650 m depth, as in this sediment clay particles are found, in contrast to St. 136. The mean grain-size declines from 143 to 144, while the mineral content diminishes with the distance from the coast of East Soemba, as might be expected if these sediments are actually composed of material from that region. In sediment 145, however, the mean grain-size as well as the mineral content, is higher than in 144. This, as well as the somewhat different mineralogical composition of the sediment indicate a completely or partially different origin of the material. Sample 145 has a higher content of acid plagioclase, biotite and muscovite than 144 and 143 and a relatively higher

situated in the Indian Ocean, the Sawoe Sea and the Banda Sea.

rutile and brookite	magnetite and ilmenite	pyrite	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Alcyonarian spicules	calcareous Sponges	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
	1					19										80	1	tr.		1		8,9
					66	66	33		1							34						0,3
					70	74	19,4	0,1	0,5							20		6		6		2,0
					56	65	28	tr.	1							29		6		6		1,5
	2	3			11	67	--30----									30	2	1		3	tr.	3,7
		5			7	66										23,5	3	5	2	10	0,5	9,5
					95	97	2	1								3						0,6
					92	93,5	6	tr.								6		0,5		0,5		1,0
					82	85	6	tr.								6		9		9	tr.	2,5
	3	0,1			20	84	--14----									14	1	1		2	tr.	4,3
		3			10	76										14	4	4	1	9	1	9,8
	1		0,2		5	28	--52----		0,3		2			1	13,7	69	3	tr.		3		24,3
					tr.	10,5	--56,5 --		2	0,5	3	tr.		3	22	87	2	0,5		2,5		8,2
			0,2	0,2	2	8,7	--88,3 --		0,3		tr.			0,2	0,5	89,3	1	1		2		6,7
							100									100						0,02
					25	25	72	0,5	0,5							73		2		2		0,3
					38	40,5	49,5	0,3	0,5							50,3	0,2	9		9,2		0,7
	tr.	4			22	37,7										56	3	3		6	0,3	1,7
		5			12	48										40	5	4	2	11	1	8,7
	2	0,3		0,5	2	49	--43----		tr.					3		46	3	2		5		17,0
					3	4	95	1								96						0,3
				0,4	18	19	--71,8 --		0,2							72		9		9		2,6
				0,5	15	18,5	--70,5 --									70,5		11		11		2,3
	tr.			0,5	3	25	--70----									70	2	3		5		6,4
					5	29										60	3	7	1	11		12,3
	1			1	20	93	0,5							0,5		1	1,5	4		5,5	0,5	3,1
							†															0,1
	0,3				20	43	8,5								0,5	9		18		18	30	0,3
					12	40,5	4								0,5	4,5		45		45	10	0,9
	0,5				10	80	1								tr.	1	3	14		17	2	1,9
					7	77										1	4	18		22		6,3
	0,1			0,3	6	10,5	--82----		tr.							82	0,5	7		7,5		2,5
tr. (4)	tr.				7	21	--74----									74	1	4		5		4,2
							98	2								100						0,1
					38	38,5	--54----		tr.						0,5	54,5	1	6		7		0,7
				1	35	37,6	--45----								0,4	45,4	1	16		17		0,5
tr. (8)	tr.	0,1		1	12	22,5	--67----		tr.				tr.			67	3	7		10	0,5	1,5
					8	28					0,5	0,1	2			61	6	4	0,5	10,5	0,5	4,3
tr.	0,3	tr.				36							0,1			63	1	tr.		1		13,9
	0,1				† 3	8,6	--90----									90	0,4	1		1,4	tr.	7,0
	0,1			0,5		2										96	2	tr.		2		8,8

garnet content; there is therefore a supply of more acid, possibly partly metamorphically altered rock material. It is not impossible that the origin of the material of sediment 145 should be sought in Middle and West-Soemba, where acid and basic eruptive rocks with contact-metamorphically altered rocks are also reported, while it is equally possible that the detritus of the whole south coast of Soemba accumulates in the deepest part of the Java trough, to which St. 145 belongs.

Sample 146, taken south of the Java trough, has the smallest mean grain-size of these four samples (fig. 22). This sediment, in correspondence with G. 94, is classified as Red Mud; the colour is somewhat browner than sample 145, but no iron-manganese concretions were detected. Besides terrigenous

components, which correspond to those of 144, the 50 cm thick sediment contains some percent little decomposed volcanic material with a very high glass content. In this volcanic glass idiomorphic green augite, hypersthene, apatite and magnetite could be demonstrated, so that it is of a pyroxene andesite composition. Nothing can be said of the origin of this volcanic ash, it may equally well be derived from a submarine point of eruption as from an earlier violent eruption of a Flores volcano, for instance.

At St. 382 there is also in the lower stratum (140—178 cm) volcanic glass from an ash eruption. Moreover both the upper layer, i.e. Globigerina Ooze 382C (0—25 cm) and 382B contain very fine terrigenous material which may be in general compared to sediment 144. The relatively higher content of quartz, zircon and tourmaline in 382C and 382B, and the presence of glaucophane, rutile and brookite in 382B indicate that at this station, moreover, material from elsewhere has been deposited (Sawoe, Timor and Australia ?).

North of the western point of Soemba at St. 148 Globigerina Ooze was found, containing some 10% terrigenous sand, a certain amount of clay and moreover, according to the appearance of the calcite and microcrystalline calcite aggregates, (table 20) detritus of limestone.

The minerals are of a pyroxene-andesite composition. The augite in it is green or pale green, the hypersthene is moderately pleochroitic. The principle fraction of the minerals is 100—50 μ.

Thus here, as near East Soemba, we have detritus of the neogene sediment covering to deal with, in this case with its tuff-sandstone and limestone. These have not been further examined in West Soemba except that Witkamp reports that the most westerly mountain of Soemba, the Djagila, is surrounded by a limstone plateau, which gradually declines to the north and north west.

The coarsest components of the neogene of Soemba were found at St. 135a in the Sawoe straits, where 2—3 cm large fragments of Globigerina-bearing marl and dark volcanic rocks were raised.

The current velocity in the Sawoe straits appears therefore to increase from St. 136, where sand was raised, via St. 135a, where only fragments from 2 to 3 cm size were procured, to the part where St. 135 and St. 134 are situated where the current is so strong that nothing is deposited. At the opposite side of the straits, near the island of Sawoe, again a sandy sediment is deposited (St. 133).

Sample S. 55 which was classified as Volcanic Mud by Böggild should certainly be considered as Terrigenous Mud, namely as detritus of neogene sediments from Soemba, considering the composition of the sediments near Soemba enumerated above. Sediment G. 95 also belongs to the Terrigenous Muds, connecting with samples 143, 144 and 145.

In the Dao Strait, between Sawoe and Rotti, there are strong bottom currents, as in the Sawoe strait, in the deepest part of the narrows, as shown by the fact that at St. 140 no sediment was found. Nearer to the coasts of Sawoe and Rotti the current is not so strong, but still considerably powerful, as at St. 139 a little shell sand and at stations 138 and 137 Globigerina Sands with few clay were found.

In the two samples 137 and 138 little sandy terrigenous material is present; in sample 137 it was 2% while in 138 it was little more than 1.5%. The diameter of this material in 137 reaches to 200 μ and in 138 to 100 μ. The mineral content and the diameter of the grains in both samples, thus, decreases from east to west, which indicates the island of Rotti as the origin of the terrigenous components of the two samples.

The mineralogical composition of 137 and 138 is principally that of hypersthene-andesitic material. The augite is pale green, the hypersthene is highly pleochroitic from green to yellowish brown, the quartz is translucent and angular. The minerals show only slight decomposition. Further 137 contains limestone detritus in the form of calcite and microcrystalline calcite aggregates, in 138 these components are barely perceptable.

The combination of only slightly decomposed volcanic products and limestone detritus, which is of the same kind as in the samples near East Soemba, make it probable that these samples also contain detritus of the upper layer of neogene sediments. Sediments 137 and 138 differ from the samples near East Soemba in containing traces of radiolarite altered into chalcedony, and that in the gravel and fraction 2—1 mm of sample 137 besides fragments of compact limestone and recent organisms are found fragments of siliceous schist and probably not recent, crinoid-particles.

The west coast of Rotti has not been examined. Brouwer (17) has been furthest west in his

researches on the island. East of Meoain he found permic coloured slates and limestone rich in tuffs, some of which contain many crinoids, brachiopods, corals and bryozoa remains and numerous fragments of porphyritic effusive rocks, chloritic substance, iron ore and plagioclase. In the slate basic camptonitic igneous rocks are found. In the same vicinity quartz porphyry tuffs, jurassic marl ironstone and trias limestone with mica sandstone were found. These older rocks are found also locally as outcrops in other places on Rotti, but for the most part Rotti, like East Soemba, is covered by neogene to quarternary Foraminifera limestones and marls, in which radiolarian earth is found. Amongst the scanty igneous rocks which have so far been found on Rotti, there are none which correspond to the mineralogical composition of 137 and 138. As it is impossible, however, that this material should be derived from volcanic eruptions of Flores volcanoes, the content of volcanic glass being too low, it must be assumed, by analogy with East Soemba, that this sandy material is chiefly detritus of neogene sediments on Rotti. Moreover there is some material of pre-neogene rocks (crinoid-limestone, radiolarite and siliceous rocks) in 137 and 138.

In the Terrigenous Mud 154 a similar, but finer material has been deposited. In mineralogical composition it greatly resembles 138. At the same time it may contain detritus from Sawoe, as well as material from Rotti, as Sawoe, in common with East Soemba and Rotti has a covering of limestone and marl gently sloping to the north.

Finally in sediment 133, to the west of Sawoe, the same only slightly decomposed, basic volcanic material occurs, but now mixed with much quartz-bearing material and with radiolarite. The components given in table 20 as radiolarite are of distinct chalcedonised radiolaria forms. Further the sample has a high content of limestone detritus, in which angular fragments of compact limestone can be detected. The gravel consists of lime- and iron oxides-bearing fine sandstone. In the rock particles a soft green rock, andesite fragments and red rock particles in which radiolaria are not certain are found. The chlorite in this sample is fibroradiate.

At St. 133, 10 km from the coast, thus a well definable collection of rock material is deposited with the Globigerina Ooze. The material corresponds entirely to the rock formations of the island of Sawoe, carried down by rivers to the west coast. According to Verbeek (168), Sawoe consists of triassic rocks, which on the coast are covered by young-tertiary marls and coral limestones. He found of traissic rocks quartz-bearing sandstones, limestones and marls, radiolaria-limestones and radiolarites. Wichmann (183) determined a green clayish rock, which he found as a boulder near Meba, as chlorite-oolite.

The sediments from stations 141 and 131 south of Sawoe (fig. 22) are both very fine-grained, they are Terrigenous Muds.

Sample 141 was too small to be able to determine the very slight mineral content. The material contained a great many clay casts and further little pelagic Foraminifera, somewhat more siliceous organisms, little calcite, few discoasteridae, and secondary pyrite.

The mineral combination of sediment 131 is between samples 133 and 382. The sediment should be considered as very fine detritus of material from the more northerly islands, without being able to determine the origin at this remote station more precisely.

From stations 130 and 156 lying to the south of Rotti, Dr. Kuenen reports (table 2) a „trace sand" and „hard bottom" respectively. This is an indication of strong bottom currents in the deepest part of the sill between the Timor sea and the Indian Ocean.

The mineralogical composition of a few scattered sediments, which contain detritus of older calc-alkali rocks is found at the bottom of table 20.

At St. 162 in the Ombai Strait, south of the islet of Kambing, an angular lava pebble, fragments of shells and a few Foraminifera, partially covered by a film of manganese were brought up; and further a little sand.

On this sill, therefore, which forms the connection between the Sawoe sea and the Wetar deep, obviously there are strong bottom currents in the narrowest part of the sill.

The sand consists chiefly of andesite particles, schisteous rock particles, mostly basic plagioclase and volcanic glas; with less, somewhat decomposed hypersthene, and very little pale green augite, green hornblende, muscovite, chlorite and tourmaline. The minerals are thus chiefly of a hypersthene-andesite composition; they form detritus from the island of Kambing, which according

TABLE 21. Mineralogical Composition of Terrigenous Muds of Group Vb,

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	orthite	zircon	tourmaline	garnet	titanite
343	5	16	11	0,3		tr.		37	2,5	2,5			1,5	0,3	0,5				1	tr.	0,8					tr.
337	5	44	23	2		1		5	1	2			5	1							1		tr.			
338	5	24	15					15	1	2		tr.	1	tr.	tr.				0,1	tr.	tr.					
82	5	3	5	1		0,5		0,2	0,5	0,3	tr.		0,3	tr.	0,3		0,3	tr.	0,5		0,4		tr.	tr.	tr.	tr.
84	S	†	†					†	tr.					tr.			tr.		tr.					tr.		
280F	1																									
	2																									
	3			0,3		0,2																				
	4		0,1	0,2		0,1		0,2											0,3							
	5	2	2	3		1		1	0,3	1			2	tr.	1				2		0,3		tr.			
	6																									
278	1																									
	2																									
	3	0,5						0,5																		
	2	14	2	4		1		0,5	0,3				tr.	tr.			0,5		7		0,1					
	5	4	3	6		2		2	0,5	0,3	tr.		0,3	tr.	0,2		0,1	0,1	10		0,4	tr.			tr.	
	6																									
352	S		†							tr.			†						†							
353	S		†					tr.	tr.				†		†				†							
299	1—5	14	12					0,3	10	0,5		0,1	1	0,2	tr.		0,1		2		tr.					
296	2																									
	3	0,5																								
	4	3	1			0,1		1									0,2	0,1	0,5							
	5	25	21	2			tr.	6	6	4	tr.		5	1	0,3		0,3		3	0,5	0,3					
	6																									
291	2	†																								
	3								tr.																	
	4	3	1					1	tr.	tr.							tr.		tr.							
	5	24	22	1	tr.			8	3	2	tr.		2	1	0,5		0,2		1		0,3					
	6																									
292	2																									
	3							tr.																		
	4	10	1					2									2		2							
	5	35	24	1	tr.			5	2	1	0,5		2	1	1		1	tr.	3	0,5	1					tr.
	6																									
293	1—5	6	20	8	1	2	0,2	1	4	3		tr.	3,5	0,5	0,5		0,3		10	0,1	0,5					
	6																									
286	P	†	†				†	†	†	†			†	†	†			†	†		†			†		
285	5	5	8	1	0,5	0,5		10	3	1			1,5	0,2	0,5		0,2		1		0,8					
284	5	30	13					15	6	2			2	1	tr.		0,2		3	0,2	0,1					tr.
283	1—5	†	†	†				†	†	†			†	†					†							
276	2							†																		
	3							1																		
	4	1	0,2					4							tr.		0,1									
	5	25	16		tr.			5	8	1			2	0,2	tr.			tr.	3	tr.	0,1		tr.			
	6																									
350	2																									
	3		0,2																							
	4	0,5	0,2					0,2	tr.	tr.							0,1									
	5	10	6					3	3	0,3			0,4	0,1	0,1		tr.	tr.	2		0,2					
	6																									
275	S		†	†		†		†	†	†			†		tr.		†		†							
260	2																									
	3	6	0,3					5																		
	4	24	4					5	0,7				0,3	tr.			0,2		0,1							
	5	35	22	0,2	0,3	0,1		4	10	0,3			2,5	0,5	0,3		0,2	tr.	3	0,5	0,8	0,2	tr.		tr.	
	6																									tr.
271	2	5																								
	3	3	1,5					0,5																		
	4	20	8					0,5	2	0,2							0,2		0,2	0,3						
	5	45	25	3	0,5	0,5		0,5	5	0,2	0,3		2	0,5	2	tr.	0,5	tr.	5	0,3	1		tr.	tr.	tr.	0,1
	6																									
269	5	20	21	3	0,5	0,2		0,5	5	0,2	1		5,5	0,5	5		0,1		10	1	2		tr.			tr.

situated in the N.E. Netherlands Indies Archipelago.

rutile	chromite and picotite	magnetite and ilmenite	pyrite	analcite	laumontite	zeolites	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Pteropods	Ostracode valves	Alcyonarian spicules	calcareous Sponges	calcite and dolomite rhomboëdra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
	0,1	tr.					0,4	25	99	tr.										tr.	1			1		10,7
		3						7	95	4										4	1			1		12,8
		1						1	60,1	--36,3--						0,1				36,4	3	0,5	tr.	3,5		29,0
	tr.	0,1	tr.					18	30,5	38	2	0,1	0,5			5		4	12,4	62	5	2		7	0,5	10,9
							†			†		†							†		†	tr.				
								90	90										10	10						0,3
								90	90				3						5	8					2	1,1
								97	97,5	1			1						0,5	2,5						5,1
								94	95	0,5	0,3		2						2,2	5		tr.		tr.		10,7
			0,5					60	76	4	2	1	1		1	2		2	10,5	23,5	0,5			0,5		20,9
			4					50	69							1				28	2	0,2	0,3	2,5	0,5	25,6
							†	†																	†	0,1
							1	89	90				6						2	8					2	0,7
								88	89	1			5						4	10					1	1,9
							0,1	60	89,5	4	0,5		1					1	4	10,5						6,4
	0,1		1					55	85	5	0,5		0,5			tr.		4	4,5	14,5	tr.			tr.	0,5	19,5
			4					53	81							tr.				14	0,9	0,1	3	4	1	20,6
																				†						
			†							†	†	†	†		†	†			†							
		1					0,5		41,7	50	1	0,1						0,1	6	57,2	1	tr.			1	76,7
								100	100																	0,11
							1	96	97,5	0,5									0,5	1			1	1	0,15
							2	88	96	1									1	2	0,5		2,5	0,5	1,1
		3				0,1	0,5	20	98	tr.								0,3		0,3	1	0,5		1,5	0,2	8,1
								4	96,8											0,5	2	0,5		2,5	0,2	24,9
								†		†																0,2
								70	70	--30----									30		tr.		tr.		0,3
								74	79	--18----									18	1	2		3		1,2
		1,8					0,2	20	87	---8,5--								0,5	9	3	1		4		5,0
								6	78,5											14	5	2	0,5	7,5	tr.	19,8
										90	8	1								99	1			1		0,3
								1	1	95	2									97	2			2		0,7
		tr.					1	3	21	56	2	0,5	0,5						1	60	8	10		18	1	1,4
		2					1	2	83	--14,1--								0,4	0,5	15	1,8	0,2		2	tr.	9,1
								2	69,5											20	7	3	0,2	10,2	0,3	22,7
		2						11	73,6	7	1	0,3	0,2	0,1	0,2	0,1		10	6	24,9	1	0,2		1,2	0,3	65,2
								3	88							0,1				10,2	1	0,3		1,3	0,5	12,1
							†			†	†															
		0,8						6	40	58	tr.									58	1	1		2		25,1
		7	tr.			tr.	0,5	3	83	12,6	0,1									12,7	4	0,3		4,3		8,8
		†							6											88	6			6		92,—
								†		†																0,1
								3	4	--93----		0,1								93,1	2	0,5		2,5	0,4	0,9
			0,2				0,2	15	20,7	--70,5--										70,5	0,5	8		8,5	0,3	1,3
	0,1	1	0,1					7	68,5	--30----										30	1	0,5		1,5		9,2
			0,1					2	63,4											30	3	3	0,3	6,3	0,3	18,1
										100										100						0,3
							0,5	6	6,7	--93,2--		0,1								93,3						0,5
							0,5	12	13,5	--84,2--		0,1							0,2	84,5	0,5	1,5		2		1,2
	0,2	0,5					0,2	6	32	--64,8--						tr.			0,2	65	2	1		3		4,0
							0,2	3	63											33	3	0,9	0,1	4	tr.	18,0
		†						†		†											†	†	†			
								99	99																1	0,3
								87	98,3	1									1	0,3			0,3	0,4	0,6
				1				55	90,3	3									3	0,3	6		6,3	0,4	2,8
	0,3	1		1	0,1	tr.		13,5	95,8	3									3	1	0,2		1,2		10,2
								5	95	1									1	2	2		4		18,2
								95	100																	0,1
								95	100																	0,2
				0,2	0,1		0,3	67	99	0,9									0,9		0,1		0,1		0,2
	tr.	1		1	0,3	tr.	0,1	6	99,8	0,1								0,1	0,2	tr.			tr.		3,7
								1	100											tr.	tr.			tr.		10,4
		1					2		78,5	---16----						tr.			5	21	0,5			0,5		6,9

Table 21. Mineralogical Composition of Terrigenous Muds of Group Vb,

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	orthite	zircon	tourmaline	garnet	titanite
268	S		†	†		†	tr.	†	†	†			†	†	†		†		†		†					
265	1	†						†																		
	2	85	2					3											7							
	3	64	12					0,2	3	1	1								14							
	4	56	12	0,5		0,2	tr.	0,1	4	2	1	0,3	2	0,1	0,1				16		tr.					
	5	35	15	4		1		0,1	10	3	1	0,2	3	1	3		0,2	0,1	9	0,5	3			tr.	tr.	tr.
	6																									
264		††	††	†		†		tr.	†	†		†	†	†	†		†	†	†	†	†				tr.	tr.
263	S	†	†	†		†		†	†	†			†	†	†		†		†		tr.					
261	2	†																								
	3	35	4			2			3	0,2		0,1							45							
	4	35	8			2		tr.	5	0,1			0,1						33							
	5	30	9	8		3	..	0,3	10	1	0,3		1	0,2	2		0,5	tr.	19	tr.	5		tr.		tr.	tr.
	6																									
262	3																									
	4	same as 261																								
	5															0,1										
	6																									

and glass, partly also hypersthene and hornblende. Some decomposition is shown in the pale green augite, the green or brown hornblende and the epidote, as in the diallaag in 278 and 279 and the highly pleochroitic hypersthene in 280F, 280D and 280. The bronzite is greatly affected, being faintly to moderately pleochroitic from pale yellow or pale pink to greenish blue.

Part of the clay casts in the samples differ from the usual composition by containing coarser particles in which Foraminifera, calcite, Sponges, Diatoms and a few fragments of volcanic material were observed.

The mechanical composition of these five samples (fig. 23) correspond in a comparatively low clay content. The mechanical analyses of 278 and 279 are practically identical; they are of the typical terrigenous sediment composition with a peak in fraction 20—5 μ. Sediments 280F, 280D and 280, nearer to the coast are somewhat coarser grained, the mechanical diagrams also show a great mutual resemblance. This indicates, like the correspondence in mineralogical composition of 278 with 279 and of 280D (98—128 cm) and 280 with 280F (0—30 cm), that the conditions under which the sedimentation has taken place have been consistent.

The sediments in the Kaoe bay are formed of detritus from the surrounding coasts and of material transported to the bay by rivers. The surrounding coast has been examined to some extent.

Wanner (173) at Pasirpoetih, on the west side of the Kaoe bay, found augite-andesite. On the south side of the bay, in and near the small river Ekor, he found a proterobase-like rock, young coral limestone on marl with recent Foraminifera, and tuffsandstone. In a tributary stream serpentine, coloured sandstone, calcareous sandstone and limestone were found. From the more southerly central mountains of Halmaheira, which are built up of a great mass of gabbroic rocks, Wanner reports partly serpentinised olivine-rock and olivine-gabbro, and a quartzitic rock.

Verbeek (168) found boulders of diabase, peridotite, serpentine and gabbro in the small river Ofiang near Waisile. He considers that between Ekor and Waisile a great part of the coast is composed of greatly serpentinised peridotite and Foraminifera-bearing limestone.

Brouwer (19) reports boulders of diorites, granodiorites, gabbro, microdiorite, diorite porphyry and limestones from a river at Ake Selaka, which lies east of St. 280 at the Kaoe bay. From the cliffs on the coast south of Ake Selaka he collected andesite tuff and large blocks of quartz porphyry to dacite.

It seems to be especially these species of rock found near Ake Selaka which have contributed to the formation of sediment 280. In the S.W. part of the Kaoe bay the sediments contain more detritus of serpentine-bearing rocks.

situated in the N.E. Netherlands Indies Archipelago.

rutile	chromite and picotite	magnetite and ilmenite	pyrite	analcite	laumontite	zeolites	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Pteropods	Ostracode valves	Alcyonarian spicules	calcareous Sponges	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
				†	†	†				†	†					†					†					
								†																		0,02
								3	100																	0,3
				3	0,3	0,5			99	tr.								0,3		0,3	0,6	0,1		0,7		7,7
		0,1		4	0,3	0,3			99	tr.								1		1	tr.			tr.		12,4
tr.	0,1	4		4	0,3				97,5	tr.								2		2	0,5			0,5		26,5
									97								0,1			2	1			1		20,5
tr.	†	†	†	†	†	†				†								†			†	†				
										†								†			†	†				
																										0,03
				9,7	1				100																	0,2
				8	1		3	4	99,2	0,5										0,5	tr.	0,3		0,3		0,5
	0,1	2		3	1	0,5	1	2	99	0,5										0,5	0,4	0,1		0,5		5,3
								0,5	97,5											0,5	1	1		2		16,5
								70																		0,2
								35						same as 261								same as 261				0,4
								10																		2,6
								2																		21,5

At St. 352, between the S.E. arm of Halmaheira and the island of Gebée, fragments of coral rock were brought up, to which Foraminifera and other organisms were attached. There was no clay and very few minerals. It appears, thus, that strong bottom currents run over this sill.

As minerals chlorite or serpentine, with little green hornblende and plagioclase, and traces of distinctly pleochroitic hypersthene were identified.

They may be derived both from the S.E. arm of Halmaheira, where Verbeek found besides low coral sandbanks, limestone and serpentine conglomerates at a higher level in the most easterly part; and they may contain detritus from Gebée, where Verbeek found partially serpentinised peridotite and gabbro.

At. St. 353 in the Halmaheira basin the sampled sediment consisted of hard, very much dried up lumps of Globigerina Ooze, which contained a great deal of clay and little sandy minerals. The minerals, as in 352, were principally chlorite and serpentine, with more plagioclase, as well as a little green hornblende and actinolite and traces of pale green augite. This material also is detritus of serpentine, gabbro and diabase, which rocks Verbeek reports in the mountains around the Weda bay, while peridotite and gabbro are reported from Gebée and Fau (Verbeek, Wichmann (183)).

In sediments 283 and 284, north of Halmaheira, old-volcanic material is present, beside a little recent-volcanic material. The older volcanic material is characterised by a relatively high content of heavy minerals. In the Globigerina Ooze 283 augite is by far the most abundant component of the rock particles, which further include labrador-andesine, hypersthene, green hornblende and magnetite. In 284 the rock particles are more strongly altered into chlorite.

Concerning the origin of the terrigenous material in these samples it should be remarked that it is probably not derived from the North Loloda islands, as Verbeek has described from the north eastern part of Dooi Tai (the largest and most northerly island) andesite covered by breccia and tuffs, in which only plagioclase occurred as phenocrysts. The material seems more connected with boulders consisting of diabase, diabase-porphyrite and augite-porphyrite, breccia and conglomerates, which Verbeek found upon North Halmaheira, Morotai and Rau. It is not impossible that similar material is residuary in the neighbourhood of St. 283, while sediment 284 may be regarded as detritus from the rocks of the above islands.

On the submarine ridge between Halmaheira and North Celebes, which forms the southern continuation of the Talaud islands, are stations 343, 285 and 286.

St. 343 at 1250 m depth lies north west of the islet of Majoe at the highest part of the westerly ridge. Here a „very firm" sediment of only 9 cm thickness was brought up, which contained terrigenous material as well as recent Roeang ash with a high glass content, especially in fraction 50—20 μ (see p. 121 and fig. 11). The terrigenous material has a peak in the fraction 20—5 μ. It contains moderately to greatly affected pale green augite and bronzite; fibrous green hornblende and actinolite, and chromite; which, together with the relatively high content of heavy minerals, indicate that older volcanic material such as diorite, diabase and possibly ultrabasic rock detritus is represented here, as in 284.

The clay casts in this sediment are partially composed of sandy minerals, and are partly green casts which sometimes contain spicules or grains of ferric oxide. The limonitic casts in this material here and there on cleavage cracks have a film of mangenese. The Rhabdamina also contain limonite and iron manganese oxides. This indicates an oxidation, which can only occur with a considerably rapid supply of water rich in oxygen. The rapid refreshment with such water would account for the extraordinarily low lime content of sediment 343 (1.3%), which only lies at a depth of 1250 m. The lime content of this sample is much lower than that of the neighbouring Volcanic Muds at 2500 m and 2650 m depth.

As this oxidation takes place, notwithstanding that the habitus of the sediment is „very firm", it must either be an older level of sedimentation which was oxidised later and upon which no renewed sedimentation took place (not counting the deposit of a little volcanic ash) or an extremely slow sedimentation in oxygen-rich water occurs. The argument may be raised against the latter supposition that Globigerina Ooze would form at this depth all the same.

The mineral composition of the sediment is of a similar kind to that of the rocks which rise above the sea in the eastern part of the submarine ridge. Verbeek (168) reports that on the small islands of Tofoerè and Majoe the older rocks crop out. On Tofoerè, 159 m high, he found serpentine, erected limestone and young coral rock, on the 379 m high Majoe diabase and slightly upheaved coral rock are found.

Sediment 343, in connection with these islands, should be regarded to a large extent as a fossil sediment, consisting of detritus of material similar to the old rocks of Tofoerè and Majoe.

Nearer to the Talaud islands on the submarine ridge both at 600 m and 2000 m depth Globigerina Ooze is deposited. Old-volcanic material is found in both samples, but it differs in composition.

The minerals in 286 consist principally of red-brown schisteous rock particles with a good deal of basic plagioclase, somewhat less chlorite and serpentine, augite (both green and pale violet augite), little volcanic glass, hypersthene (pleochroitic from pink to greenish blue) and green hornblende, and traces of a chalcedony-bearing siliceous rock, radiolarite, red hornblende, epidote and muscovite.

This mineralogical composition may be compared with the rocks which according to Roothaan (135) occur on the Talaud islands. The centre of the most southerly island, Kabroean, is formed of eruptive rocks which are irregularly surrounded by usually reddish brown, radiolarite-like siliceous schists. Furhter there are a breccia formation composed of eruptive rocks, siliceous schists and limestone, a marl sandstone formation and reef limestone. The eruptive rocks of Kabroean are chiefly derived from gabbroic and peridotitic magmas; the last rocks are almost entirely altered into serpentine. Amongst the potassium-gabbros and dolerites of Kabroean and Karakelang Roothaan has described rocks with titaniferous augite (pale violet, purplish brown), on Kabroean basalt is also found.

In sediment 286 the detritus of siliceous schist formations with that of potassium-gabbros and dolerites is the most important. In contrast to this only the old eruptive rocks are represented in sediment 285.

The mineralogical composition of 285 greatly resembles 284; green hornblende is more plentiful in 285 than in 286 and titaniferous augite is absent. The terrigenous components of 285 have a peak in fraction 100—50 μ, they are, therefore, more coarse-grained than in 284.

The origin of the material in 285 is probably to be found in diorites and gabbros of the Talaud islands.

In the sediments 291 and 292, to the south west of the Talaud islands, siliceous rocks cannot be detected. Amongst the rock particles there are some which contain much serpentine; other consist chiefly of plagioclase and volcanic glass with some hypersthene and augite, these rock particles are practically unaltered. The mineral composition of these two samples is distinguished from the rest of the sediments from this area by a relatively higher plagioclase content. The pyroxenes are strongly affected, beside pale green augites there are some pale violet ones, as in 286. Amongst the green hornblendes idiomorphic specimens were found, which were sometimes encrusted in volcanic glass; they form a part of a sporadic admixture of Banoea Woehoe material.

The material of samples 291 and 292 which, as shown in fig. 23, belong to the medium-grained terrigenous sediments, may be derived from the gabbroic, dioritic and peridotitic rocks of Kabroean, and possibly from other Talaud islands, in which basalt detritus (Roothaan describes both augite-potassium-basalt and labrador-basalt) is more common than in the other sediments from this area.

At St. 293, 10 km north of Karakelang, the largest of the Talaud islands, a sandy sediment is found (fig. 23). This sediment consists for a great part of material of the above basic and ultrabasic rocks, the augite in it is green or pale green, the hypersthene is distinctly pleochroitic. Further, radiolarian forms consisting of fibrous chalcedony can be clearly distinguished, there is also limestone detritus, in which a few coral particles were observed.

The composition of sediment 293 corresponds to that of the rocks on the north coast of Karakelang. According to Roothaan the igneous rocks in the bay of Bamboeng can be observed as cliffs in the surf; on the N.W. coast also, eruptive rocks, partially surrounded by siliceous schists occur. Breccia are reported from the shore near Bamboeng as solid rock.Further on the N.E. and N.W. coast raised reef limestone is met with.

The correspondence in mineralogical composition between the sandy sediment 293 and the medium-grained sediment 296 of the Sangi trough is very striking (table 21). The examination of a greater number of samples from this region would be necessary to ascertain in how far the material of 296 may be derived from the island of Karakelong.

The mineralogical composition of the other sediments in table 21 is characterised by a relatively high content of heavy minerals, of which augite is the principle constituent, while the hornblende content varies.

At St. 299 at 1400 m depth pebbles with a coating of manganese were brought up and at 1500 m depth the same, with coarse sand chiefly of 1—0,2 mm diameter (fig. 25). This sand consists half of pelagic Foraminifera, so that the sediment is classified as Globigerina Ooze. In the rock particles plagioclase and green augite with little distinctly pleochroitic hypersthene is found, in the plagioclase zoning is observed. The hornblende is green or brown, the biotite dark brown or red. The chlorite is largely secondary and sometimes fibroradiate.

It is difficult to give an indication of the origin of this little decomposed material, as at the neighbouring stations no volcanic material was found. Strong bottom currents are more obvious at these stations 298 (coral with coating of manganese), 300 and 297 (hard bottom) even than at St. 299 in the Kawio Strait. The most probable supposition is that the terrigenous material in sample 299 is derived from the Sarangani islands. On the most westerly island, called Baloet, Musper and Neumann van Padang (117) report an extinct volcano of 833 m height.

I have not found any description of material from this volcano or from the Sarangani islands, except the report by Iddings (81) (Vol. II, p. 619) that the great bulk of all the volcanic rocks of the Philippine islands is andesite, mostly pyroxene-andesite. Many rocks are hornblende-pyroxene-andesites, fewer are hornblende-andesites without pyroxene and still fewer have biotite. Some carry olivine. Basalts form some of the more prominent and active volcanoes.

The sand in sample 299 may be detritus of augite-andesite with very little olivine and biotite, in which the content of heavy minerals has been relatively raised, as compared to the content in the original rock, by currents or breakers.

The sample raised at St. 289 in the Siaoe Strait consisting of coral and pebbles with a coating of manganese demonstrates the presence of strong bottom currents between the Sangi trough and the Celebes sea.

Between the S.E. point of Mindanao and Karakelong the strong bottom currents from the Pacific Ocean to the Sangi trough, as well as from the Sangi trough to the Celebes sea south of the Sarangani islands, do not seem to be confined to the sills alone.

Stations 267 and 268 lie between East Mindanao and the islet of Miangas on a narrow ridge reaching to 1500 m depth. Here, at a depth of 400 m and 750 m respectively, a trace of sand and a trace of material which, considering the depth, contained few calcareous organisms were raised. It is thus obvious that at these stations the currents have a great effect, the bottom current seems to be stronger at St. 267 than at 268 as at the latter station clay has been deposited. It may be assumed that over the sill between St. 268 and Miangas very strong bottom currents run.

Between Miangas and Karakelong lies the sill, which forms the connection between the Pacific Ocean and the Sangi trough, at some 2050 m depth, as reported by van Riel (130). Near this sill at St. 294 Kuenen reports a small amount of marl and sand with coating of manganese, from a depth of 1850 m. The composition of sample 294 indicates the effect of fairly strong bottom currents on the spot. At St. 295, close to the south of Miangas, a fair amount of deep-sea corais and pebbles (photo 1) were raised from 850 m depth, indicating a strong bottom current at a great distance from the sill.

There are also strong bottom currents over the sill between the Pacific Ocean and the Morotai basin, as Kuenen reports from St. 288 at 2200 m depth „a trace hard clay in unclosed jaws", so that it appears that there is no recent sedimentary covering at this station.

At St. 270, at a depth of 4600 m in a steep part of the westerly slope of the Mindanao trough, the instrument hit upon a „hard, very irregular bottom". This makes it probable that at this station material has slid down, as St. 270, in contrast to the above mentioned stations, lies at a great distance from the sills over which transport of water from the Pacific Ocean to the Sangi trough and the Morotai basin takes place.

The mineralogical composition of the samples raised near N.E. Mindanao (262 and 261) and south and east of cape S. Agusin (268, 265 and 264) show a great mutual resemblance. It is detritus of basic and ultrabasic and of slightly metamorphic rocks. Moreover traces of radiolarite were detected in 265 and 268, while a few fragments of siliceous rocks were found in 261. Limestone detritus was found only in 265. The samples correspond in containing many rock particles and much serpentine, chlorite and zeolites, and in a high content of pale green and green, sometimes yellow-green augite. In the rock particles there are much serpentines, in which sometimes remains of olivine and rhombic pyroxene can be recognised; besides these there are chlorite-schists, actinolite-schists, actinolite-epidote-schists (fibrous actinolite with nests of epidote in a medium of acid plagioclase) and little gabbro and andesite.

The serpentine is mostly fibrous, curved in a fan shape, yellow, green, blue-green or red-brown in colour. Fibroradiate aggregates of chlorite or serpentine are also present. The rhombic pyroxene is moderately to very faintly pleochroitic from pink to pale bluish green; there are both bronzite and optically positive enstatite, sometimes showing striae parallel to length and they may be dusty from inclusions. There are moreover a few strongly lamellated forms of enstatite-augite. The hornblende is usually green, occasionally brown in colour. The plagioclase is partly translucent with sometimes zonal structure and with inclusions of augite or green hornblende, partly dusty or more or less altered into saussurite. The quartz consists of translucent angular fragments, or of quartz aggregates. The apatite is partly translucent and partly dusty. In the zeolites analcite, exhibiting none or slight birefringence predominates; beside which fibrous and „platy" aggregates of laumontite occur. Amongst the occasional zeolite rosettes with R.I. = $\pm$ 1,48—1,49 there is probably some chabasite.

The mineralogical composition of 268, 265 and 264 is distinguished from 261 and 262 chiefly by a higher content of rhombic pyroxene and hornblende. The difference is thus of degree.

The mineralogical composition of these five sediments corresponds to the rocks in the Cordillera in the extreme eastern part of Mindanao. Smith (154) says „our knowledge of the geology of the rocks of this region is extremely limited"; the researches of various investigators show that the Cordillera has a core of igneous rocks, which has undergone some metamorphisms. Smith reports as volcanic rocks diabase, diorite, gabbro and serpentines, of which the parent rock in Surigao is

probably a peridotite, and further younger basalt and felsitic to porphyritic andesites. Of metamorphic rocks there are chlorite-schists, micaceous schists, actinolite-schists, epidote-magnetite-schists, serpentines, old slates and marble. Of the sedimentary rocks partially covering the core of rocks, igneous conglomerates, tuffsandstones and crystalline limestones, including lepidocyclinal limestone are mentioned; moreover locally silicified wood, and a rock made up of coral stems, all completely silicified are met with. Radiolarian chert and jasper are according to Smith exceedingly limited in its outcroppings and quite variable in its phases, never being encountered as a continuous formation, but only as isolated outcrops, which reveal little or nothing as to its position. Smith compares its occurrence to that of the radiolarites and hornstones in the Danau-formation of Borneo described by Molengraaff.

Samples 261, 262, 268, 265 and 264, in accordance with the above, contain chiefly material from igneous and slightly metamorphic rocks, while radiolarite-bearing rocks occur locally in very small quantities. The low content of limestone detritus is due to the great depth at which they are deposited, whereby calcareous products may dissolve to a great extent before settling.

The mechanical composition of these sediments (fig. 23) indicates that the material to the east of South Mindanao contains more fine sand than the deposits east of North Mindanao. The fact that the mean grain-size declines from 265 towards 264 confirms the opinion that the material of these sediments is derived from Mindanao.

The high rainfall on East Mindanao (some 3000 mm per year), the steep coast and the heavy breakers undoubtedly promote the denudation of this part of the island.

At St. 263 the sediment is still finer and richer in clay than at St. 264. The brown colour and the presence of grains of manganese are a reason for classifying it under Red Clay.

Judging by the mineralogical composition the sediment joins with the above five sediments which are deposited east of Mindanao, as it contains constituents of the same species of rocks. But in 263 detritus of volcanic rocks, serpentines and limestones are more evident, while the content of the other metamorphic rocks is lower. The hornblende-, plagioclase- and calcite content, namely, is higher, the actinolite and epidote content is relatively much lower in 263, while zeolites were not detected.

From similar material appears thus to have been deposited Terrigenous Mud nearer to the coast, while a Red Clay was formed by more slowly sinking finer particles, transported over a greater distance and in well oxygenated water.

The minerals of the Coral Mud 269, near the Nanoesa islands, mostly are of 100—20 μ diameter (see fig. 27 and table 26).

The mineralogical composition much resembles 263, except for a higher actinolite and epidote content.

St. 269 lies about 5 km S.E. of the small islands of the Nanoesa group, called Maroka, Kakarotan and Intata. According to Roothaan the core of Kakarotan and Intata is formed of rocks of the sandstone formation, while coral reef limestone occurs on all the three islands. On Kakarotan he found detached pieces of igneous and siliceous rocks of coarse-grained structure, which, if compared with the material from the Talaud islands, would belong to the lowest strata of the sandstone-marl formation. The material of these islands would then be derived from dioritic, gabbroic and peridotitic magmas, which agrees with the composition of the terrigenous components of sample 269. It is also possible that the terrigenous material of sample 269 is derived entirely or partially from Karakelong. Considering the mineralogical composition of sample 269 (table 21) slightly metamorphic rocks appear to occur in this region, as on Mindanao. Roothaan encountered contact metamorphic rocks but he has given no description of them. The coral sand found in sediment 269 with the Globigerina Ooze, judging by its coarse sand measurements, could only have been transported for a short distance, it must, therefore, be derived either from the Nanoesa islands mentioned above or from submarine coral reefs.

It is more difficult to ascertain with any certainty the origin of the terrigenous material of sediments 260 and 271 lying in the southern part of the Mindanao trough, about 150 km to the east of Karakelong. This part of the Mindanao trough is severed from the Talaud and Nanoesa islands by the Snellius ridge, at the east side of which, at least at St. 270, sliding down of material might well occur.

It is remarkable that both in sample 260, which is of the typical mechanical composition of Terrigenous Mud (fig. 23) and the very fine and firm Terrigenous Mud 271, the content of rock particles and heavy minerals is comparatively so high. It is assumed that in the transport of material over a long distance the heavier components sink more rapidly than the lighter ones of the same grain-size and that therefore the content of rock particles and heavy minerals will decline relatively, as can be observed in the sediments S.E. of Soemba in the Java sea. Only when the transport takes place with great rapidity, like that of the volcanic ashes in the Celebes sea, or when the sediment is composed of precipitated or sliding material, or deposited near a steep coast, can the original content of heavy constituents be maintained. The relatively high content of rock particles, in which chlorite-schists and andesite particles can be distinguished, these samples have in common with 265 and 264, as well as the presence of analcite and laumontite, while the clay casts mostly consist of sometimes sfaerolitic chloritic aggregates. It is therefore not impossible that these sediments are formed from material that has been transported southwards through the Mindanao trough, the content of heavy components beeing still higher in 265 than in 260 and 271. It seems more probable, considering the possibility of falling and sliding of the material along the wall of the trough (St. 270) that sediments 260 and 271 are composed of loose products from the Snellius ridge. If this is the case it would form a mineralogical indication that the Snellius ridge (or flank of the Mindanao trough) like the Talaud islands (cf. Roothaan bibl. 135) forms a unity with East Luzon, East Mindanao and Halmaheira. In this connection the collection and examination of solid rock like that encountered at St. 270 would be of great interest.

Station 275, N.E. of Morotai, also lies in the Mindanao trough, which is only 5550 m deep here, while the walls of the trough are much less steep in this region than at St. 270.

Here a trace of mud was raised, which proved to contain chiefly clay particles, with the minerals given in table 21 and with few siliceous organisms. It is remarkable that there are no rock particles. This fine sediment which is deposited at 80 km from the coast of Morotai, is probably composed of material from the island. The principle rocks occurring on Morotai, as has been said above, are diabase, diabase-porphyrite and augite-porphyrite.

From the small amount and fineness of the material deposited at St. 275, which lies in the deepest part of the southern extension of the Mindanao trough it may be concluded that only little material from Morotai is transported in an easterly direction.

The Mindanao trough, as reported by van Riel (130) turns off eastwards at about 2° N. St. 276 lies in the deeper part (4300 m) of this continuation of the trough. St. 350 lies south of St. 276 at 2600 m depth in a part where the sea-floor, after rising and falling, finally becomes less deep to the south.

Both sediments are rich in clay, the mineral content of 276 is higher than of 350 and the content of heavy minerals is both relatively and absolutely higher in 276, while apart from that the mineralogical composition of the two sediments is strikingly similar. It is therefore hardly possible that the material has been supplied from a southerly direction. The sediments are formed chiefly of detritus of basic igenous rocks; minerals of the metamorphic rocks and zeolites, which form an important part of the sediments more to the north in the Mindanao trough, are here of subordinate significance. They are thus probably derived from detritus of rocks from the N.E. arm of Halmaheira and even from Morotai and the N. arm of Halmaheira.

The N.E. arm of Halmaheira is little known. Brouwer (19) traversed it from Dodaga to Boeli, encountering chiefly diorites, gabbros, serpentine and amygdaloidic diabases with neogene limestones and hornstones in the core-mountains of the N.E. arm.

On the whole the content of detritus of metamorphic rocks in the sediments of Group V, which lie in the north eastern Indian Archipelago, seems to increase as we come more N.N.E. The Talaud and Nanoesa islands form a transition region. Near the Nanoesa islands (269) the content of minerals of metamorphic rocks is remarkably higher than in the sediments near the Talaud islands (293, 292, 286).

To judge by the mineralogical composition of the sediments there is a possibility that the Snellius ridge and the Nanoesa islands form a petrographical unity with the eastern cordillera of Mindanao.

The Terrigenous Muds examined from the eastern Netherlands Indian Archipelago may chiefly be regarded as detritus of the surrounding islands. The deposition of material, from which these terrigenous sediments are formed, carried to the sea by rivers or coastal erosion may or may not be effected by marine currents.

Only a small number of sediments appear to be formed by material from submarine ridges or shelves (98, 182, 260 and 271). The meeting with a „hard bottom" at St. 270 might also be accounted for by the sliding of material from the steep slope on which this station lies.

No indication of the mode of formation of a few medium-grained sediments (358, 362) was found. A more close net of sampling in the part of the Banda sea and the Weber deep in which these stations lie, would give a better insight into the distribution of this material and would aid considerably in the research for the origin of it.

In a few cases the presence of fossil deep-sea sediments seemed admissible in areas of small sedimentation. Small settling velocities may be the consequence of a limited supply of terrigenous material, as seems to be the case in the eastern Java sea (26, 28); apparently it occurs frequently in connection with bottom currents or marine currents.

3. GLOBIGERINA OOZE.

Distribution

The Globigerina Ooze occupies a greater space in map I than in the map by Böggild (8). This is due chiefly to the fact that during the Snellius-expedition various regions were sampled which had never been sampled before. Thus Globigerina Ooze proves to be widely distributed in the Ceram-Timor outer arc, along the coast of New Guinea and the Sahoel shelf, by the islands of Rotti, Sawoe and Soemba and in the Soeloe sea. It is also found along the eastern edge of the Soenda shelf. On the other hand, the continuous area of Globigerina Ooze which Böggild gives north of the Volcanic Muds of the Flores and Banda seas is broken several times by Terrigenous Muds, here caused by a great local supply of terrigenous material (Gulf of Boni) as well as by the partial dissolution of calcareous particles in deeper and more oxygenated water (northern Banda sea).

In the vicinity of the Talaud islands and between the Sangi islands and Mindanao, Globigerina Ooze is deposited upon submarine ridges to a depth of 2000 m.

Murray and Renard's (115) hypothesis that from out the coast a sequence of Terrigenous Mud — Globigerina Ooze — Red Clay occurs, was not confirmed in the Pacific Ocean east of Mindanao. The Terrigenous Mud here gradually merges into Red Clay of similar mineralogical composition (St. 263). The lime content found by Murray and Renard in the samples from the Challenger-expedition C. 215, C. 216, and C. 216A (see table 1) allow the conclusion that in the area between the Palao islands and the most southerly part of the Mindanao trough the boundary between Globigerina Ooze and Terrigenous Mud lies at some 4000 m depth. This is given on the map. In the more northerly part of the Pacific Ocean the boundary seems to lie at a smaller depth, but the sea-floor is here almost more than 4000 m deep.

Locally Globigerina Ooze was found in the Molukken sea, in the southern Banda sea, near the south east arm of Celebes and north of Soembawa. No doubt further researches will reveal more of these local areas of Globigerina Ooze.

In drawing the boundary between the Globigerina Ooze and the other sediments I made use of the investigations of other expeditions as well as of these of the Snellius-expedition. Moreover I took into consideration:

1. the local lime-content of the sediments at different depths,
2. the mouths of large rivers,
3. steep coasts,
4. the presence and distribution of recent-volcanic material.

The lime-content of the sediments and the formation of Globetina Ooze

The formation of Globerina Ooze, in accordance with the researches of Andrée (2), Correns (37), Schott (144), Wattenberg (175), Trask (161) a.o. depends upon:

1. The extent to which pelagic Foraminifera are produced in the upper layers of the deep-sea ($\pm$ 0—100 m), as pure Globigerina Ooze consists principally of pelagic Foraminifera with a comparatively small admixture of other calcareous and siliceous organisms. After their death the calcareous shells of these organisms sink to the bottom of the sea, in so far as they do not go into solution during the process of sinking.

No quantitative data are known as to the amount of pelagic Foraminifera which are produced in the upper layers of the seas of the eastern Indian Archipelago.

The calcium carbonate content of the sediments in general and therefore of Globigerina Ooze depends upon:

2. The carbonic acid and oxygen content of the sea water; an increasing content of carbonic acid increases the solution of the calcareous shells, while the oxygen content of the water determines and limits the formation of carbonic acid. An important factor is the high oxygen content of the cold polar water which moves from the poles to the equator at depths greater than 3000 m.

3. The temperature of the sea-water; the solubility of the calcium carbonate increases with decreasing temperature.

4. The pressure of the water; the solubility of the carbonate increases with increasing pressure.

5. The salinity of the water; the solubility of the carbonate increases with the decline of salinity. The salinity varies most in the surface water, it shows little variation with depth, according to Trask (161).

6. The current velocity of the sea water; the more rapidly water rich in carbonic acid and oxygen is supplied, the more calcium carbonate will go into solution and the calcium bicarbonate formed will be more rapidly carried away. It is thus not necessary that the sediments on the spot have a high content of organic matter to account for the formation of carbonic acid from organic matter and oxygen, the formation of carbonic acid may have taken place elsewhere to a great extent.

7. The admixture of terrigenous components naturally diminishes the calcium carbonate content of the sediments.

These factors are not all independent of eachother, there is, for instance, a correlation between the carbonic acid content of the water and the temperature, the pressure and salinity of the water.

Indirectly there is also a connection between the depth at which the sediment is deposited and its carbonate content, as in general the temperature of the sea water falls and the pressure rises with an increase of depth. However, the carbonic acid content and the current velocity of the water are more important factors in the lime content of the sediments.

The distribution of Globigerina Ooze in the eastern Neth. Ind. Archipelago is limited and the carbonate content of the sediments is comparatively low.

If the calcium carbonate content of the upper stratum of the sediments from the Snellius-expedition at various depth be compared with those from the Challenger- and Siboga-expedition in the East Indian Archipelago and with that of the sediments in the open oceans according to Murray and Renard (table 22), it will be seen that for the first mentioned samples the variation in carbonate content in the different depths is also very great. The mean values move in about the same order of magnitude as those of the samples taken earlier in this region. The calcium carbonate content in the sediments of the East Indian Archipelago remains far below that of the sediments in the open oceans; at a depth of about 5500 m however, the lime content of the two regions approach eachother and at depths greater than 5500 m the difference does not exist.

For these greater depths, however, the number of samples from the inland seas of the East Indian Archipelago is too small to be able to draw more conclusions from a mutual comparison.

The principle cause of the difference in carbonate content of the sediments in the East Indian Archipelago and in the open oceans, as Molengraaff (114) has reported, is the relatively rapid settling velocity of terrigenous detritus and of recent-volcanic products in the region of the Archipelago. This cause becomes very evident if the different types of sediment from the Snellius-expedition are arranged according to their relative calcium carbonate contents measured with regard to the mean values as they are given in table 22. These relative lime contents are given on map III for the samples from depths of less than 5500 m, while in table 23 they are taken together for the various types of sediment.

TABLE 22. Calcium carbonate content of the sediments in the East Indian Archipelago.

Depth	Snellius-expedition: number of samples	Snellius-expedition: variation in $CaCO_3$-content	Snellius-expedition: mean % $CaCO_3$	Challenger- and Siboga-expedition: number of samples	Challenger- and Siboga-expedition: mean % $CaCO_3$	Snellius-, Siboga- and Challenger-expedition: mean % $CaCO_3$
0— 500	18	5,6—89,2	44,3	26	43,2	43,7
500—1000	26	7,6—68,9	40,1	16	38,0	39,3
1000—1500	27	1,3—91,7	40,6	12	31,2	37,7
1500—2000	24	7,1—58,8	31,0	10	32,2	31,3
2000—2500	23	2,9—63,3	22,8	11	24,0	23,2
2500—3000	29	1,5—69,6	25,6	9	25,7	25,6
3000—3500	17	0,5—54,3	16,5	4	23,7	17,9
3500—4000	13	2,4—49,0	16,2	4	8,4	14,3
4000—4500	13	0,7—38,3	10,2			
4500—5000	9	1,8—43,9	10,9			
5000—5500	13	0,5— 5,9	2,1			
> 5500	10	tr. —23,5	4,4			
> 4000	45	tr. —43,9	6,7	14	2,1	5,6

Calcium carbonate content of the sediments in the open Oceans according to Murray and Renard.

Depth in m	number of samples	mean % $CaCO_3$
1— 900	14	86,04
900—1800	7	66,86
1800—2700	24	70,87
2700—3600	42	69,55
3600—4500	68	46,73
4500—5400	65	17,36
5400—6300	8	0,88
6300—7200	2	0,00
> 7200	1	tr.

TABLE 23. Relative calcium carbonate content of the sediments from the Snellius-expedition

Type of sediment	Number (and percentage) of samples in every group: 1	2	3	4	5
Volcanic Mud	7 (35)	10 (50)	3 (15)		
Terrigenous Mud	12 (14)	44 (50)	24 (27)	7 (8)	1 (1)
Terrigenous + Volcanic Mud . .	8 (24)	8 (23)	16 (47)	2 (6)	
Red Clay		1 (100)			
Globigerina Ooze.		1 (2)	18 (30)	32 (52)	10 (16)
Coral Mud			1 (12)	1 (12)	6 (76)
Total number of samples	27	65	62	42	17

group 1: Calcium carbonate content extremely low.
„ 2: Calcium carbonate content lower than the mean content in the E. I. Archipelago.
„ 3: Calcium carbonate content = mean content for E. I. Archipelago.
„ 4: Calcium carbonate content between that of group 3 and group 5.
„ 5: Calcium carbonate content = mean content in the open Oceans.

The calcium carbonate content of the Volcanic Muds, the Terrigenous Muds and the sediments formed from these two Muds, prove to be generally lower, or equal to, the mean calcium carbonate content in the E. I. Archipelago. An exception is formed by Terrigenous Mud 276, from the Pacific Ocean; and the sediments 102, 125, 186 and 187, consisting for a great part of terrigenous limestone or coral rock detritus, which owing to their composition cause local accumulations of calcareous matter; and the Terrigenous Muds 210 and 216, which are deposited in the vicinity of a limestone-rich coast, but contain little limestone detritus in the sand fractions. Further, in this category are the Volcanic + Terrigenous Muds 205 and 373 and the Terrigenous Mud 369, which are possibly deposited in an area where the terrigenous material settles at a slow rate.

The calcium carbonate content of the Globigerina Oozes and Coral Muds is usually above the mean value of the sediments from the Snellius-expedition or they correspond to the mean lime-content of these sediments.

This variation is not only dependent upon the degree of admixture of terrigenous or recent-volcanic material in these types of sediments, but also upon the composition and current-velocity of the water in the basins.

The deposits in the sea south of Timor illustrate clearly the effect of the terrigenous admixture upon the relative calcium carbonate content of the sediments (map III). The relative lime content here increases regularly with the distance from the coast of Timor, while the mineral content falls with the distance.

A low relative lime content in consequence of the high settling velocity of Terrigenous Mud occurs in the Makassar Strait lying between two large islands, in the western Ceram sea and in the narrow Kaoe bay of Halmaheira; the same effect is also produced to a less degree in the northern Banda sea and in the Sawoe sea. At the same time strong currents in the northern Makassar Strait, in a part of the Ceram sea, in the Manipa strait and in the northern half of the Banda sea, have the same effect of lowering the relative lime content.

In the northern Banda sea the recent-volcanic products of the Gg. Banda Api have locally diminished the relative calcium carbonate content of the sediments; while the same effect is produced in the southern Banda sea by recent-volcanic products of the Batoe Tara, the Gg. Api North of Wetar, the Woerlali on Dammar, of Téon, Nila and Seroea, and partially also by terrigenous material.

In the Flores sea and the Bali sea the Tambora ash, and locally the Sangean volcano (St. 169), have even more effect in reducing the calcium carbonate content in the sediments than terrigenous deposits, in just those places where there are strong currents from west to east.

In the eastern half of the Celebes sea the combined effect of very strong currents, the low temperature of the water and the supply of recent-volcanic material are felt upon the lime content of the deposits. These factors cause the low content in the middle of the Celebes sea. In the vicinity of the Soeloe islands their influence becomes less. Along the coasts of Borneo and North Celebes the calcium carbonate content is diminished by terrigenous deposits.

In the Sangih trough and its continuation in a southerly direction parallel to the Sangih islands and the Minahassa (296, 291, 343, 79, 340 and 337), and from the Morotai basin to the Ternate through and Batjan basin (345, 346, 347 and C. 196), the combined effect of strong currents and recent-volcanic or terrigenous deposits upon the lime-content of the sediments is again noticeable.

The effect of the proximity of the coast upon the calcium carbonate content of some of the sediments in the Pacific Ocean (265, 350, 276) is clearly shown in their composition.

The relatively low calcium carbonate content of the sediments on the Soenda shelf in the eastern Java sea may be attributed partly to the deposition of terrigenous material and perhaps partly to the locally less favourable conditions for organic life.

In the sediments of which the relative calcium carbonate content corresponds to, or approaches, the mean value of the sediments in the open oceans, three groups may be distinguished, according as to whether the cause of the relatively high lime content is to be found in:

1. The closing of the basin by a shallow sill or the absence of a supply of well oxygenated water of low temperature.
2. The local absence or small amounts of terrigenous material.

3. The lime-bearing terrigenous detritus or coral detritus deposited near to the coast or to coral reefs.

The sediments in the Soeloe sea belong to the first group (St. 64, 65, 66 and 67). Kuenen (98) and van Riel (130) have pointed out that this basin has a very shallow connection with the Celebes sea, at not more than 300 m depth, through the Siboetoe strait. The temperature of the water in the basins below the sill-depth is determined by the temperature of the water at the deepest sill of the basin. Van Riel reports that the potential bottom temperature in the Celebes sea, where there is a sill at some 1400 m depth, is 3°,29 C and in the Soeloe sea 9°,85—9°,89 C. Further, in the Celebes sea there is a rapid transport of this well oxygenated water of low temperature derived from the Pacific Ocean, while the Soeloe sea receives its poorly oxygenated water from the China sea across a sill to the west of Panay. The temperature of the water is therefore higher and the oxygen-content lower in the Soeloe sea than in the Celebes sea, while the transport must take place through a long and narrow channel. This accounts for Globigerina Ooze being deposited at great depths in the Soeloe sea, while it is almost entirely absent in the Celebes sea.

Sediment 353, lying in the Halmaheira basin also owes its comparatively high calcium carbonate content to the fact, that, as Van Riel reports (130) „the bottom water in the Halmaheira basin is renewed by a transport from the Pacific Ocean, across the northern sill" and that „the saddle-depth of this sill amounts to about 700 metres". In the Halmaheira basin a minimum potential temperature of 7°,55 C has been observed at station 353 near the bottom. Thus here also, the cold water does not reach the basin because of the high position of its sill.

The Globigerina Oozes 29, 88, 93, 94, 105, 106B, 364, 368, 370, 374, 200, 233, 283, 285 and 320 and the Coral Muds and Sand 124, 129 and 182L belong to the second group. The Globigerina Oozes 84, 85 and 86 and the Coral Sand 60, of which the calcium carbonate determinations are missing, undoubtedly also belong to this group in virtue of their composition.

These samples lie either upon submarine ridges or in the vicinity of shelves. As the oceanographers report that the velocity of the currents increases with the distance from the sea-floor, the finer terrigenous material will be carried over the ridges and banks by the rapid currents to settle in the deep basins and troughs; the sandy calcareous organisms will then be relatively better represented on these banks and ridges, which accounts for the relatively high lime-content of these sediments.

The Terrigenous + Volcanic Mud 373 formed between the small islands of Romang and Damar probably owes its relatively high lime-content to a low settling velocity of the terrigenous material in this region.

The transition from group 2 to group 3 is formed by sediments 73, 92, 116, 117, 118, 122, 123, 128, 138, 185, 188, 193, 206, 236, 237, 242 and 248. These sediments lie mostly upon submarine ridges or in the vicinity of shelves, while they are, moreover, near to a limestone-rich coast or to coral banks, the detritus of which is present in these sediments.

The most typical Globigerina Oozes belong to group 2 and to this transition group.

The third group is formed by sediments 269, 354A, 328, 102, 110, 125, 137, 133, 136, 148, 186, 187, 189 and 201. These samples naturally come from the vicinity of limestone-rich coasts or of coral banks. Moreover in sediments 205 and 369, which have a relatively high calcium carbonate content, detrital lime not derived from organisms was identified, possibly this material in 205 consists of detritus from the coral reefs of the Toekang Besi islands.

In the Ceram-Timor outer arc the greatest variation in relative calcium carbonate content is met with. The variations occur chiefly in strips which run parallel to the coast. Sediments 327 and 87 by the coast of Ceram have a moderate relative calcium carbonate content, owing to a strong admixture of terrigenous material. The Globigerina Oozes 328, 88, 93 and 94 somewhat further from the coast, as they lie upon ridges contain less terrigenous material and show a relatively higher calcium carbonate content. In the deepest part of this sea the fine-grained terrigenous sediments 355, 325, 89, 324 and 95 with a relatively low calcium carbonate content have collected. The Globigerina Oozes 84, 85 and 86, situated between Obi and Misool, are subject to the same conditions as 88, 93 and 94. The Globigerina Ooze 91 has a relatively low calcium carbonate content owing to the admixture of a good deal of terrigenous material brought by the rivers from the Vogelkop. Sediment 96 has a moderate calcium carbonate content as it is a denudation product of a coast rich in limestone. The same applies to sediment 92.

TABLE 24. Composition of Globigerina Oozes in the Eastern an

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	tremolite	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	epidote and zoisite	andalusite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite
353	S		†					tr.	tr.		†			†				†										
354a	S		†	†		†			tr.	tr.	†	tr.					†	†	tr.									
82	1																											
	2																											
	3																											
	4																											
	5	3	5	1		0,5		0,2	0,5	0,3	0,3	tr.		0,3		0,3	tr.	0,5	0,4			tr.	tr.	tr.	tr.		tr.	0,1
	6																											
84	S	†	†					†	tr.			tr.				tr.		tr.					tr.					
85	S																											
86	S																											
327	1																											
	2																											
	3																											
	4			3	tr.	0,5		0,5									2	tr.										
	5			23	0,5	13		0,5		tr.	tr.	tr.		4		tr.	3	3	4			tr.	tr.	tr.	0,1			
	6																											
328	1																											
	2																											
	3					0,2																						
	4	1	tr.	1		1		0,1			tr.						1	0,5	tr.									
	5		1	15	0,3	9		0,5	tr.	0,3	1	0,1	tr.	2	tr.	0,2	8	2	1			tr.	tr.	0,1	tr.		tr.	0,2
	6																											
87	1																											
	2																											
	3		tr.	5		8																						
	4			8		12		tr.								tr.								tr.				
	5		tr.	6		10		tr.	tr.	tr.	tr.			tr.		tr.	tr.		tr.			0,1	tr.	tr.	tr.	tr.		
	6																											
88	1																											
	2																											
	3								tr.																			
	4		0,1	0,1												tr.												
	5		0,3	2		2,6		tr.	tr.	tr.	tr.			tr.			tr.		tr.			tr.	tr.	tr.				
	6																											
91	1																											
	2																											
	3								tr.								tr.											
	4		0,1	0,2		0,1				tr.						0,1	tr.											
	5		0,5	10	tr.	15			tr.	tr.	tr.			tr.			tr.	1	tr.		tr.	tr.	tr.	tr.		tr.	tr.	
	6																											
92	1																											
	2																											
	3			tr.																								
	4		1	2		2		1	0,1							tr.	0,9	tr.										
	5		3	4	0,3	5		0,5	tr.	0,1	tr.	tr.		tr.		tr.	2	tr.	tr.	tr.	tr.	tr.	tr.	tr.			tr.	
	6																											
93	1							†																				
	2															tr.												
	3							tr.								tr.												
	4		tr.					tr.		tr.																		
	5		0,5	0,2	tr.	0,3		0,5	tr.	0,1	tr.					tr.	0,3					tr.	tr.					tr.
	6																			tr.								
94	1																											
	2																											
	3																											
	4																											
	5		0,2	0,2		0,2			tr.	tr.	tr.			tr.			tr.		tr.			tr.	tr.			tr.	tr.	
	6																											
103	1																											
	2																											
	3																											
	4		1																									
	5		8																									
	6		25																									
99	S		few																									
364	1—5			0,1	tr.	0,1			tr.	tr.	tr.			tr.			0,2		tr.			tr.		tr.				tr.
	6			2		1				tr.	tr.			0,1		0,2	4						0,1					

South-Eastern part of the Netherlands Indian Archipelago.

pyrite	barite	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Alcyonarian spicules	calcareous Sponges	coccolithes	discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
†							†	†	†			†			†	†					†							
†			†				†	†	†				†			†			†	†	†		†					
					68	68	7							3							22	32						0,2
					84	84	15	0,5													0,5	16						1,4
					72	72	25	0,5	0,5												1	27	1			1		3,7
					51	51	40	2	0,5												1	43,5	1	4	tr.	5	0,5	4,5
tr.					18	30,5	38	2	0,1			0,5				5				4	12,4	62	5	2		7	0,5	10,9
1					7	24										3						65	8	2	0,1	10	1	20,9
				†			†		†												†		†	tr.				
			15			15	80	tr.		3		2	tr.									85						
							70		1	8		16			1							96	4			4		
																											†	0,04
					2	2	96	tr.	1													97					1	1,9
		1		4	5	93	1															94	1			1		8,2
			6	tr.	1	13	85	1	0,5													86,5	0,2	tr.		0,2	0,3	11,3
1			0,5	0,5	2	55,3	43,5	0,2	tr.							tr.						43,7	1			1		21,4
1					2	76												tr.	0,5			22	1	0,5	tr.	1,5	0,5	14,2
							†														†						†	0,25
			10			10	87	1			2											90						0,5
			4		14	18,2	79	1	0,5													80,5	1	0,3		1,3		2,3
0,5			1	1	12	19,2	75,5	0,5	tr.											0,3		76,3	1	3		4	0,5	1,9
3			0,3	tr.	8	52	44	0,2	0,4							0,3			tr.	0,1		45	2	0,5		2,5	0,5	11,8
3					2	65																32	2	0,7	tr.	2,7	0,3	18,4
																				†								0,1
5			30			35	60	3	1				1									65						1,5
1			30		6	50	--50----															50						10,8
0,5			20	0,5	8	49	--50----		1											tr.		51		tr.				13,8
0,5	tr.	tr.	4	1	5	27	--72----		0,5											0,5		73	tr.	tr.				7,5
0,5			0,5		4	22																75	2	0,8		2,8	0,2	6,9
6						6	64	6		8			4								12	94						0,3
			4			4	92	3	0,5													95,5	0,5			0,5		7,6
			20		1	21	--78----		1													79						45,5
			20	tr.	2,8	23	--77----															77						9,3
0,3	tr.	0,2	4	tr.	0,5	10	--90----		tr.													90	tr.			tr.		10,4
0,3			0,5		0,5	12	--86----															86	1	0,5		1,5	0,5	3,8
				5		5	2	20	8	20	8	2	tr.								35	95						4,6
			2	7		9	57	8	5	9	1	1									10	91						9,0
			6	7	8	21	52	8	3	5		1									10	79						18,5
			20,5	5	5	31	48	12	1			1									7	69						12,7
1			10	2	2	41,5	40	10	1							tr.					7	58	0,5			0,5		7,8
2			1	1	1	63										0,1						36	0,5			0,5	0,5	6,4
							†	†		†																		0,2
			1		2	3	92	3													2	97						4,6
			0,5		4	4,5	--95----		tr.													95	0,5	tr.		0,5		8,4
			1	1	4	13	--75----					0,5								2	7	84,5	0,5	2		2,5		15,0
tr.		tr.		3	6	24	--53----		0,5			0,5			tr.	1				15	5	75	1	tr.		1		24,9
					9	29										3			tr.			68	2	1	tr.	3		16,2
							†	†																				0,1
					4	4	94	2	tr.													96						1,6
			3		3	6	--93----		tr.													93		1		1		10,7
1			1		4	6	--92----		tr.												1	93	tr.	1		1		4,1
3			1		3	9	--90----		tr.													90	0,5	0,5		1		10,5
4					2	12																83,5	2	2	0,1	4,1	0,4	8,4
							†	†																				0,1
			6			6	91	1													2	94						3,7
			13		2	15	--85----															85						14,1
			10		1	11	--89----		tr.													89	tr.			tr.		14,7
2		tr.	2	0,1	1	6	--94----		tr.													94	tr.			tr.		15,5
2					1	5	--94----															94	0,5	tr.		0,5	0,5	9,9
					70	70	15	1													14	30						0,5
			15		35	50	--50----															50						6,3
			12		4	16	--84----		tr.													84						17,5
			23		6	30	--70----		tr.													70						15,3
3			6		10	27	--72----		0,5							0,1			0,1	0,3		73	tr.	tr.		tr.		6,3
7					14	46													2			53	0,3	0,2		0,5	0,5	5,7
tr.			†		†		†	†																				
				1	0,5	2	95	1	1													97	1			1		95,5
				1	10	18,5	--78----															78	2	1	0,3	3,3	0,2	0,8

Table 24. Composition of Globigerina Oozes in the Eastern a

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	tremolite	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	epidote and zoisite	andalusite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and
105	1																											
	2																											
	3															tr.												
	4															tr.												
	5			0,3		0,7			tr.	tr.	tr.								tr.			tr.	tr.			tr.		
	6																											
106B	1																											
	2																											
	3															1												
	4			0,1		0,1										0,2	0,2											
	5		tr.	0,5		1,5			tr.	tr.	tr.					0,1	0,1		tr.			tr.	tr.	tr.				
	6																											
106A	1																											
	2																											
	3															0,5												
	4					tr.																						
	5			1		2,5					tr.						tr.	tr.	tr.				tr.					
	6																											
110	1																											
	2																											
	3			tr.																								
	4			0,5		1,5										tr.												
	5		tr.	0,5		1,5			tr.	tr.	tr.						tr.	tr.	tr.			tr.	tr.	tr.		tr.		tr.
	6																											
109	2																											
	3															0,8	0,2											
	4			0,3	tr.	0,7										0,5	0,1											
	5		tr.	1	tr.	3			tr.	tr.	tr.			tr.		0,1	0,2		tr.			tr.	tr.					
	6																											
108	2															tr.												
	3																											
	4			tr.												tr.												
	5			0,5		1,5			tr.		tr.			tr.		0,1	0,2		tr.			tr.	tr.	tr.	tr.			
	6																											
107	1																											
	2																											
	3																											
	4								tr.							tr.	tr.											
	5		tr.	8	0,1	18			tr.	tr.	tr.			tr.		tr.	1	0,5	tr.			tr.	tr.		tr.	tr.		
	6																											
112	2																											
	3								tr.																			
	4		tr.			tr.											tr.											
	5		tr.	tr.		tr.		tr.	tr.	tr.	tr.			tr.					tr.									
	6																											
368	2																											
	3																											
	4															tr.												
	5		0,1	1	0,1	1		tr.	tr.	tr.	tr.	tr.		0,2		tr.	0,1	tr.	0,1			tr.	tr.	tr.				
	6																											
370	1																											
	2																											
	3																											
	4			tr.							tr.																	
	5		0,5	4		2			tr.	tr.	tr.			0,1	tr.	tr.	0,5	0,3	0,4		tr.	tr.	tr.			tr.	tr.	tr.
	6																											
374A	2																											
	3			0,3																								
	4		2					1			tr.					tr.	tr.											
	5	7	8	10	0,3	3		8	0,5	,05	0,5			0,2		0,5	0,1	0,4	1			tr.	tr.	tr.	tr.			1
	6																											
374F	1																											
	2																											
	3		0,3	0,3																								
	4		†	†		†		†			tr.					tr.	†											
	5	†	†	†	†	†		†	†	†	†			†		†	†	†	†			tr.	tr.		tr.			†
	6																											
374C	1																											
	2																											
	3																											
	4	1	0,5	0,1		0,1		2	0,1		0,1					0,1		0,1										
	5	†	†	†	†	†		†	†	†	†			†		†	†	†	†			tr.	tr.	tr.	tr.			†
	6																											

South-Eastern part of the Netherlands Indian Archipelago.

pyrite	barite	X	glauconite	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Alcyonarian spicules	calcareous Sponges	coccolithes	discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
0,5 1 1		tr.	2 5 3 1		1 1 0,5 4 4	3 6 4 7 9	† 88 89 90 86	6 3 3 2	† 1 1 1 1			tr. 0,5	1			tr. 1,5			0,5		† 1 1 2 3,2	97 94 96 92,7 88	tr. 2	0,5		tr. 2,5	0,3 0,5	0,06 2,0 16,9 7,2 18,1 9,4
2 tr. 0,5			1 3 20 10 3	0,5	2 1 0,4 1 1	3 5 22 11 6,7 8	93 92 --77-- --88-- --90--	2	1 0,5 0,5 0,5							tr.			0,3		3 0,5 0,5 0,8	96 95 78 89 91,3 89	0,1 1 2	tr. 0,5 0,5		0,1 1,5 2,5	1 0,5 0,5	1,2 9,2 40,4 9,5 14,5 5,0
60 50 24 5 14 10			40 8 20 11 3	1 0,5	0,5 6 8 6	100 58 45 23 29 71	--40-- --55-- --75-- --70--		1 1 0,5							tr.			0,2		1 1 0,5	42 55 77 71 28	tr. tr.	tr.		tr. tr.	1	0,5 0,6 0,6 0,8 1,2 3,6
tr. tr. 1 1			3 4 1		2 5 12 12 3	2 8 18 16,2 8,5	70 --74-- --55-- --55--	† 17	† 1 5 2		†	1 5 1			1 2 1	3 4			0,1		† 10 15 15 20,5	97 92 82 82,5 90	1 tr. 1 1	tr. tr. tr.		1 tr. 1 1	0,3 0,5	0,2 0,9 2,1 5,1 12,7 19,3
2 2		tr.	0,3 0,5		55 43 38 17 8	55 44 40 24 20	--45-- --55-- --57-- --75--		0,3							0,2 0,2			0,1		tr. tr.	45 55 57 75,5 75	tr. tr. 0,3 2	0,5 3 0,2 2		0,5 3 0,5 4	0,5 1	0,4 2,8 1,2 5,2 7,4
0,5 1,5 3		tr.	0,5 2 1	0,2	15 9 25 10 12	15 10 27 15 23	82 --90-- --72-- --82--	3	0,3 0,5							0,1 0,5			0,5		0,5 0,2	85 90 72,8 82,8 71	1 3	0,2 1 2	tr.	0,2 2 5	0,2 1	1,3 3,2 5,1 6,4 7,4
1 0,5			2 0,5	0,2	49 50 37 6 6	49 50 37 36,8 17	† 49 --50-- --62-- --61--	1	tr. 1					1		1 1			tr. tr.		†	51 50 62 63 80,5	tr. 0,5 0,1 1	tr. 0,5 0,1 1	0,2	tr. 1 0,2 2,2	0,3	0,06 0,8 3,8 2,4 10,7 18,0
0,5 tr. 2 5				0,5 tr. 0,1	4 14 30 22 16	4 15 30 24,3 26	--93-- --84-- --67-- --73--		0,1							0,1 0,5			0,1		3 1 1	96 85 68 73,2 67	tr. 1 3	2 1 3		2 2 6	0,5 1	0,4 1,2 1,2 1,9 5,9
			0,1		3 10 15 7 5	3 10 15 9,8 10	--97-- --88-- --81-- --88--									tr. 0,5			0,3			97 88 81 88 83,5	0,5 1 1 3	1,5 3 1 3	tr.	2 4 2 6	0,2 0,5	0,9 3,9 2,2 5,7 10,3
				tr. 0,3 1	0,1 0,5 2	0,1 9 17	100 99 99 99 --90--	1 1 0,5	tr.							0,2			tr.		0,1	100 100 100 99,6 90,2 80	tr. 0,5 1,5	tr. 0,3 0,3 1		tr. 0,3 0,8 2,5	0,5	0,1 8,4 14,3 13,1 16,9 12,7
				0,2 1 2 0,5	0,5 3	1 4 43 45	-100-- --98-- --89-- --54--		tr.											1		100 98 89 55 50	0,9 1 1,9 3,5	0,1 6 0,1 1	tr.	1 7 2 4,5	0,5	1,1 2,6 4,3 10,1 16,2
				0,1 † †	0,3	1 10 38	† -100-- --99-- --88-- --60--	†	tr.													100 99 88 60	tr. 1 2	1 tr.		tr. 2 2		0,2 2,7 4,0 1,7 8,7 18,3
0,1				tr. 0,3 † 0,5	0,2	tr. 4,7 33 32	† -100-- -100-- --95-- --65--									tr.			tr.			100 100 95 65 65	0,3 2 2	tr. 0,5		0,3 2 2,5	0,5	0,04 2,7 6,1 8,5 14,8 15,8

Table 24. Composition of Globigerina Oozes in the Eastern and

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	green and brown hornblende	red hornblende	tremolite	actinolite	glaucophane	biotite	muscovite	chlorite and serpentine	epidote and zoisite	andalusite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite
374B	1																											
	2																											
	3							0,2																				
	4		tr.														tr.											
	5	†	†	†	tr.	†		†	†	†	†			tr.		†	tr.	†	†			tr.		tr.	tr.			†
	6																											
374E	1																											
	2																											
	3																	0,1										
	4	3	2	2		0,5		4		0,1	0,3			0,1		0,2	0,5	0,1										
	5	†	†	†	†	†		†	†	†	†			†		†	†	†	†			tr.	tr.	tr.	tr.			†
	6																											
374D	1																											
	2																											
	3																											
	4	0,2	0,2					0,5	tr.		0,1					0,1												
	5	†	†	†	†	†		†	†	†	†			†		†	†	†	†			tr.	tr.	tr.	tr.			†
	6																											
374H	1																											
	2																											
	3					tr.																						
	4	0,2	0,1	tr.				0,5		tr.								tr.										
	5	†	†	†	†	†		†	†	†	†			†		†	†	tr.	†			tr.			tr.			†
	6																											
115	2																											
	3					tr.																						
	4		2	0,1		0,1			tr.		0,1					tr.												
	5		3	1,5		1,5		0,1	0,3	0,1	0,3	tr.		0,6			0,5	0,2	0,5			tr.		tr.	tr.			1
	6																											
116	2															1												
	3			0,5												0,5												
	4		tr.	0,2	tr.	tr.										0,1	tr.											
	5		tr.	0,5	tr.	0,2		tr.	tr.		tr.			tr.		tr.	0,1		0,2			tr.	tr.	tr.				
	6																											
117	1																											
	2																											
	3																											
	4					tr.											tr.											
	5		tr.	1		0,3			tr.	tr.	tr.			tr.		tr.	tr.		0,1			tr.	tr.	tr.	tr.	tr.	tr.	
	6																											
118	2															2												
	3		tr.													1,7	1											
	4		tr.	0,3							0,1					0,3	tr.											
	5		0,5	5		4		1	0,3	0,2	0,2	tr.		0,4		0,3	1	0,2	0,8			tr.		tr.	tr.			
	6																											
122	2																											
	3																											
	4			0,3		0,3										tr.												
	5		tr.	0,2		0,2		tr.	tr.	tr.	tr.			tr.		tr.	0,2		tr.			tr.	tr.	tr.	tr.		tr.	
	6																											
123	2																											
	3		tr.																									
	4		tr.																									
	5		tr.	tr.	tr.	tr.		tr.	tr.		tr.	tr.		tr.		tr.	tr.						tr.					
	6																											
128	1																											
	2																											
	3			tr.																								
	4																											
	5	0,1	0,3	0,3		0,1	tr.	0,1	tr.	tr.	tr.			tr.		tr.	tr.	tr.										
	6																											
382C	2																											
	3		tr.					tr.																				
	4							tr.																				
	5		0,5	0,3		0,2		2	0,3	0,1	0,1			tr.				tr.	0,3			0,1	tr.	tr.	tr.			0,1
	6																											
382B	2																											
	3		tr.																									
	4		tr.					6																				
	5		0,5	0,3		0,3		12	0,1	0,1	0,1	tr.		tr.	tr.				0,2			0,1	tr.	tr.		tr.		tr.
	6		3	1		1		12	tr.	tr.		tr.				tr.												

South-Eastern part of the Netherlands Indian Archipelago.

pyrite	barite	X	glauconite	limonitic casrs	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Alcyonarian spicules	calcareous Sponges	coccolithes	discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
					0,3 tr.	0,5 tr. 7 24	† --99---- --99---- --99---- --90----	†	1 tr. tr.									tr.	tr.			100 99 99 90 73	0,5 tr. 2 2	1 1 0,5		0,5 1 3 2,5	0,5	0,07 3,1 11,1 6,6 14,7 15,4
				tr.	0,2	0,1 13 30 35	† --99---- --99,5 -- --86---- --67----	†	1 tr.													100 99,5 86 67 64	0,4 0,9 2,5 0,6	0,1 0,5 0,2		0,4 1 3 0,8	0,2	0,1 2,0 6,2 9,4 18,9 16,1
tr.				0,5	0,2 10 † 3	0,2 11 28 29	† -100---- --99,5 -- --87---- --70----	†										tr.	tr.			100 99,5 87 70 66	0,3 1 2 3,5	1 tr. 1		0,3 2 2 4,5	0,5	0,01 3,0 4,2 5,9 10,6 16,6
tr. tr.				tr. †	0,2 1	tr. 1,2 25 36	† -100---- -100---- --98---- --72----		0,3 tr.									tr.				100 100 98,3 72 60	tr. 0,5 2,5 3,2	0,5 0,3		tr. 0,5 3 3,5	† 0,5	0,05 3,8 7,1 7,5 11,9 15,2
tr. 0,5		tr.		0,5 0,5 0,5	55 25 44 24 15	55 25 46,8 34,3 27	45 73,5 50 --62,5 --	0,5 0,2	tr. tr.							0,2 0,1					1	45 75 50,2 62,7 60	tr. 1 5	3 1 3	tr.	3 2 8	tr. 1 5	0,5 0,5 2,5 2,9 8,6
				0,1 tr.	4 18 24,5 24 15	5 19 25 25,2 23	--95---- --80---- --72---- --72----									tr.						95 80 72 72 72	0,3 0,3 3	0,5 2,5 2 1,7	0,1	0,5 2,8 2,3 4,8	0,5 0,2 0,5 0,2	0,5 1,3 2,5 4,3 7,1
		tr.		0,5 0,3	3 4 6,5	3,5 6 9,5	† 97 --99---- --96---- --84----	3	tr. 0,1			0,1	tr.			2,5 2			tr.	3	† 1 tr. 2,3	100 100 96 92 86	1 3	0,5 0,5 1	tr.	0,5 1,5 4	0,5 0,5	0,2 5,4 6,8 5,5 9,5 9,3
1 1				0,3 0,3 0,3	3 9 14 9 10	5 12 15 24,3 36	95 --82---- --80---- --65----		0,5			0,2				2 0,5			0,5	2	tr. 1	95 82 80 70,7 57	1 0,3 1 3	4 3,7 3 1,7	0,3	5 4 4 5	1 1 1 2	0,2 0,7 0,5 2,2 7,1
1 1		tr.		0,2 0,1	25 40 45 25 10	25 40 45,8 27 22	75 --59---- --54---- --70,5 --		tr. tr. tr.							0,5 2			tr.			75 59 54 71 72	0,5 1 3	0,5 0,2 1 1,9	0,1	1 0,2 2 5	1	0,7 2,8 1,4 3,6 8,4
				tr.	35 60 60 30 20	35 60 60 30 22	--60---- --35---- --33---- --50----		tr. 0,5 1			0,5			0,2	4 9			0,5	10	5 3 3 1,8	65 38 37 67 74,4	2 2 2,9 3	1 0,1 0,3		2 3 3 3,3	0,3	0,6 4,3 3,8 14,4 22,9
0,5 0,5				tr. tr. 0,1	tr. 0,2 2 2	tr. 0,2 3,5 8	† -100---- -100---- --99---- --90----		0,3 0,3						tr.	3 3	0,1	0,5	0,1	1	0,3 0,7	100 100 99,6 95 89	1 2	0,2 0,2 0,5		0,2 1,2 2,5	0,3 0,5	0,05 1,8 2,0 1,3 3,0 8,2
				tr. 0,3	5 6 6	tr. 5 10,5 10	-100---- -100---- --85---- --82----		tr.													100 100 85 82 80	tr. 0,5 1	tr. 10 7 8,5	0,5	tr. 10 7,5 10		0,3 0,4 1,4 2,5 5,8
5					tr. 17 7 11	tr. 23 21 33	100 --97---- --60---- --74---- --53----		tr.												3	100 97 60 74 56	tr. 1 2	3 17 4 8,5	0,5	3 17 5 11		0,1 0,4 2,3 4,2 7,4

The relative lime content of the sediments in the Aroe basin declines from the west, where sample 102 is a denudation product of a coast very rich in limestones, toward the east. Sediments 104 and 98, from the east of the Aroe basin, are terrigenous denudation products from New Guinea and the Aroe islands poor in lime. Sediments 97, 103, 100 and 101 occupy an intermediate position.

Stations 364, 105, 106B and 99 again lie upon ridges, they receive little supply of material from the land and show a relatively high calcium carbonate content. The composition of 106A (see table 24 and fig. 25) which represents a lime-poor, clay-rich lower stratum, proves that the conditions have undergone a change at St. 106.

The Globigerina Ooze 110 near the Tenimber islands is rich in carbonate as it contains lime-rich detritus from the island of Jamdena. The Terrigenous Mud 111 is relatively poor in lime, probably because it contains a great deal of fine mud from the rivers of Australia. The intervening Globigerina Oozes 107, 108, 109 and 112 contain a relatively moderate amount of lime.

The relative calcium carbonate content of the sediments south of Timor and the Sermata islands, in contrast to those lying south of the Tenimber islands, increases regularly from the coast of these islands towards the Sahoel shelf, while the content of terrigenous components in the sediments falls constantly. Only the Terrigenous Mud 125 forms an exception, which is accounted for by its containing limestone detritus derived from Timor. Sediments 116, 117, 118, 122, 123 and 128 owe their relatively high lime content probably partly to coral rock detritus, in the sand fractions of 117, 118, 123 and 128 fine calcareous debris could be observed, which was not derived from Foraminifera.

Van Riel (130) reports that „the bottom layers of the Timor trough are renewed by water from the Indian Ocean crossing the sill to the south of Rotti at about 1940 metres". The occurrence of strong bottom currents at Sts. 130 and 156 south of Rotti corresponds with this.

The boundary between Globigerina Ooze and Terrigenous Mud, taking into account all the deep-sea deposits so far sampled, lies in the Indian Ocean at St. 382 at about 3600 m depth, to the east at St. 131 the boundary lies above 3000 m and with an increased admixture of terrigenous material in the southern half of the Timor trough it lies at the 2000 m. line, while along the Timor side no Globigerina Ooze occurs because of a more rapid deposition of terrigenous than of organic material; to the south of Moa, where the terrigenous admixture becomes less pronounced, the boundary again falls to the 3000 m line to change again to the 2000 m line south of the Babar island group. In the western Aroe basin the boundary lies at about 2000 m, in the eastern part of the basin there is no Globigerina Ooze for the same reason as near Timor.

It is thus evident that within the same basin the lime content of the sediments varies very much at equal depths. A close connection cannot be expected, therefore, between the lime content and the depth of the sediments in the inland seas of the Archipelago.

Near the islands of Soemba, Savoe and Rotti also a sharp contrast may be observed in the lime content of the sediments. On the shelves surrounding these islands relatively lime-rich Globigerina Oozes are deposited, owing to the presence of limestone-bearing detritus from the islands. In the straits between the islands there are, however, strong currents, so that at Sts. 134, 135 and 140 there is no deposit at all and at St. 135a there are only fragments of rock and marl of 2—3 cm diameter. At stations 141 and S. 55 sediments were found with relatively low lime content. The Globigerina Oozes 148 and 143 contain limestone detritus, in 143, however, there is relatively much more old-volcanic material.

The contrasts seen in the relative lime content of the sediments in the Gulf of Boni and the adjacent part of the Banda sea are due to the variety in nature and quantity of the terrigenous material contributed.

Sediments 186 and 187 deposited in the 3370 m deep Saleyer trough are chiefly composed of terrigenous material very rich in lime. The high calcium carbonate content of the deposits is evidently effected to some extent by the bottom current which renews the bottom-water of the Saleyer trough at the east side over a sill at 1350 m depth (van Riel), as otherwise a calcium carbonate content would be expected here not lower than the mean in the open oceans. Sediment 200 (1100 m deep) and 188 (1000 m deep) lying respectively upon a submarine ridge which connects the southern arm of Celebes with the Tijger islands, and to the west of Kabaëna, do in fact show a calcium carbonate content which corresponds to that of sediments in the open oceans.

In sample 200 no limestone detritus was identified, the sediment however also contains very few mineral terrigenous components. In sediment 188, there is again limestone detritus, but relatively much less than in 186 and 187, further 188 contains more mineral particles than sample 200. Sediment 188 is one of the most typical Globigerina Oozes of the eastern East Indian Archipelago.

In sediments 189 I—V and 189 A—C lying near the southern arm of Celebes at 2 km distance from one another, the calcium carbonate content varies in a vertical direction. In the first sediment the relative calcium carbonate content of the upper layer of 0—11 cm is equal to the mean for the E. I. Archipelago, while in the four lower layers it alternates above and below the mean. In the other sediment, of which three layers were sampled, the relative calcium carbonate content of A (0—6 cm) and B (68—74 cm) is above the mean at this depth, while in C (162—168 cm) it is below the mean. Correspondingly, the content of mineral components of 189 III, 189 V and 189 C is higher than in the other samples, while the content of limestone detritus is highest in 189 IV, 189 A and 189B (table 25). In the layer 189 I both the mineral content and the content of limestone detritus are low.

Here, therefore, at the very same spot the effect of the nature and composition of the supplied terrigenous material upon the lime content of the sediment is demonstrated. It has even lead to the deposition of alternating layers of Globigerina Ooze and Terrigenous Mud.

The sediments of St. 193 at a distance of 0,2 km from eachother, in contrast to those at St. 189, show practically no difference from one another, the five different layers, also, which have been sampled from the 174 cm long sediment, show hardly any variation. They are all Globigerina Oozes with a low mineral content and a small content of limestone detritus.

The Terrigenous Muds from the Gulf of Boni 191A and B, 190 and 192 have a relatively low to medium lime content, although they all contain limestone detritus. The content of mineral terrigenous components is, however, much higher in proportion than the limestone detritus.

Sediment 206, by the Toekang Besi islands, belongs to the sediments to which calcareous debris is supplied, containing coral rock detritus. It is possible that similar material occurs in the fine fractions of sediment 201.

In sediment 73, near the island of Siboetoe and sediment 269, near the Nanoesa islands a part of the calcareous debris is also formed by coral rock detritus.

In samples 206 and 73 the mineral content is low, samples 201 and 269 contain a moderate amount of minerals.

The Globigerina Ooze 185, situated by the S.W. point of Celebes, contains detrital lime, while the same was found sporadically in the Globigerina Ooze 328 north of Ceram.

As pointed out already by Dr. Kuenen a peculiar feature of table 22 is the increase of carbonate from 2500—3000 meters. This may be merely accidental, but it is shown in both columns.

My objections to the conclusion, that the bulge in the line giving the relation between depth and lime of the Snellius samples, is typical for the deposits in the Molucca's are: 1. the total number of samples is much too small as compared to the strong variations in lime content, 2. the bulge between 1000 and 1500 m depth for the combined Siboga and Challenger samples runs exactly contrary to that for the Snellius samples and the divergence both ways is equal. 3. The explanation may be that the lower average of the 23 samples between 2000 and 2500 m depth as compared to the average of the 29 samples between 2500 and 3000 m depth can be attributed chiefly to the fact that 5 of the former have an exceptionally low percentage of lime, against only 2 of the latter group. The former 5 were obtained in regions of swift sedimentation (Makassar strait and Ceram sea), and the same is the case for the latter two (Ceram sea and an almost pure volcanic ash).

The calcareous organisms of the Globigerina Oozes do not differ fundamentally from those of the other deep-sea sediments. They will be treated in a separate chapter with the siliceous organisms.

The mechanical composition of the Globigerina Oozes

In figures 24, 25 and 26 the mechanical analyses of the Globigerina Oozes are graphically represented. These diagrams are divided into four groups in figures 24 and 25, while in 26 the diagrams of the samples of sections are given.

TABLE 25. Composition of Globigerina Oozes in the Central, Western and Norther

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite	pyrite	leucite and analcite
137	1																																
	2																																
	3		1,5					0,5	tr.																								
	4		4			tr.		0,5	tr.																								
	5	1	8	tr.		tr.	tr.	1	tr.	0,2			tr.						tr.														
	6																																
138	1																																
	2																																
	3							tr.																									
	4	2	2					0,5		tr.																							
	5	1	2	0,5		0,2	tr.	2	tr.	0,2			tr.							tr.			tr.										
	6																															0,1	
133	1	†						†																									
	2	2																															
	3	4	4	1,4		2	0,1	1		0,5																							
	4	3	5	8		12	1	0,5	1	2										tr.	tr.				tr.						0,3		
	5	5	4	8		12	2	3	0,2	0,5			0,1			tr.				0,5	0,2		tr.		0,1	tr.			tr.		0,3	tr.	
	6																																
136	1																																
	2	1																															
	3	0,7	4					tr.	2	4																					0,3		
	4	2	4					2	2	4																					1		
	5	3	5	0,5		0,3		3	2	4			0,1								0,1		0,1								1		
	6																																
143	2	1																															
	3	tr.						tr.																									
	4	2	0,3	0,2		0,2		5											0,2	0,2													
	5	9	7	6		1		12	0,5	0,8	tr.		0,7						0,5	0,5	3	0,1	3		tr.		tr.	tr.			2	0,3	
	6																															0,3	
148	1																																
	2																																
	3	1	0,2					0,3		tr.																							
	4	8	5	0,3				2	1	0,5			0,2	tr.																	0,1		
	5	5	9	1		0,3		4	1,3	2			0,2						tr.												1		
	6																															tr.	
174	1	15	5					25																									
	2	9	2					11	1																								
	3	9	5					15	1				tr.						1														
	4	30	5,5					11	2			tr.	0,5						0,5														
	5	23	13					11	6	tr.			1,5						1												0,5		
	6																														1		
34	1	5																															
	2																																
	3							tr.											1														
	4	2	1	1				2	0,1										2		tr.												
	5	3	5	12	1	6		1	2	0,5			0,5			0,5	0,1		0,5	tr.	1	0,4	0,3		0,2		tr.				0,5	1	
	6																															3	
29	1																																
	2																																
	3																																
	4							tr.																									
	5		0,5	1		1		0,2	tr.				tr.						tr.													0,2	
	6																															1	
185	1																																
	2	tr.																															
	3							tr.																									
	4							0,5											0,5														
	5	1	1		1			1	2	tr.				0,4					0,5		tr.										tr.	tr.	0,1
	6																														tr.	0,2	
200	1	†																															
	2	tr.																															
	3		0,3										0,2																				
	4		0,4						0,1				0,1																				
	5	tr.	0,5	0,2	0,1			0,2	0,1				0,1	tr.					tr.	tr.													
	6																																
1891	2																																
	3																																
	4																			tr.													
	5		†	†	†	†		tr.	tr.				tr.	tr.		tr.			tr.	tr.	tr.		tr.									1	
	6																															2	

glauconite	manganese oxides	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Lamellibranches	Gastropods	Pteropods	Ostracode valves	Crinoid fragments	otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
					†	†	†	†	†	†			†	†																1,3
			3	3	80	10	1			2	1	0,5		0,5	1									96	1			1		17,8
			4	6	--79----						1												13	93	1	tr.		1		36,5
			3,5	8	--65----		1				1						2						22	91	1	tr.		1		11,3
			tr.	10,5	--56,5---		2										0,5	3		tr.		3	22	87	2	0,5		2,5		8,2
				10														2	0,1	4	1			87	2	0,5		2,5	0,5	2,0
			93	93	3	2								2										7						1,8
		3	5	8	90	0,5	0,3							0,1		0,1								91	1			1		18,7
			10	10	--89----																			89	1			1		39,7
2		0,5	2	9	--89----		0,1															0,1	0,8	90	0,5	0,5		1		14,3
0,2		0,2	2	8,7	--88,3---		0,3											tr.				0,2	0,5	89,3	1	1		2		6,7
			1	14														0,3	0,1	tr.	tr.			80,4	4	1	0,1	5,1	0,5	3,0
					†	†			†	†																				1,6
				2	94	3				0,5		0,2		0,3										98						14,9
			1	14	--72----		1			1													12	86	tr.			tr.		19,9
				33	--10----		1			1							1					3	51	67	tr.	tr.		tr.		19,1
				36	--16----		1										0,5	4			0,1	7,4	34	63	1	tr.		1		13,9
				36														2	0,1	0,5	0,5			61	2	0,5	0,5	3		6,9
					3		10	5	1	5				1	10								65	100						6,4
		1		2	75	6	2	2		4	1	1			3	tr.	1						3	98						24,3
				11	66	3	1			10		tr.					tr.						8	88	1	tr.		1		31,6
				15	44	3	1			4							2	tr.					30	84	1			1		25,2
				19	--40----		2			2							1	2					33	80	1	tr.		1		8,9
				8														2		tr.				88	2	1		3	1	0,6
				1	--99----																			99						0,6
			1	1	--97----																			97	0,5	1,5		2		1,8
			2	10	--82----		tr.																	82	1	7		8		3,1
		0,5	2	49	--43----		tr.															3		46	3	2		5		17,0
			0,5	40																				51	3	5	1	9		19,5
					†	†								†									†							0,2
					100	tr.																		100						3,9
10			3	14,5	--74----		0,5	0,5			0,5												8	83,5	2			2		24,6
3			4	24	--60----		0,5																14,5	75	1	tr.		1		8,6
0,2			5	28	--52----		0,3											2				1	13,7	69	3	tr.		3		24,3
			4	29														6						65	5,8	0,1	0,1	6		14,1
				45	--30----									5									15	50					5	0,2
			1	24	--75----																		1	76						3,0
			3	34	--65----																		1	66	tr.	tr.		tr.		21,7
			3	53	--45----																		1	46	tr.	1		1		7,8
			1,5	58	--30----		tr.											tr.					10	40	1,5	0,5		2		23,5
			1	36														2						57	6	1	tr.	7		10,8
				5	5																		70	75	20			20		0,1
					--65----																		20	85	15			15		1,1
tr.			2	3	--70----		1				3						tr.						12	86	11			11		18,8
tr.			4	12	--64----		0,5				3						0,1	0,3				1	15	84	4			4		7,9
0,3		0,2	2	38	--37,2---		0,5				1						0,3	3				2	17	61	1			1		12,1
			3	38														1			tr.			60	1	tr.		1	1	10,8
						†	†			†				†									†		†					0,04
20				20	62	5	1							1									7	76	4			4		1,4
25				25	64	2	1																7	74	1			1		13,7
24				24	67	2	1																5	75	1	tr.		1		29,9
10		0,1	5	18	70	2	1											tr.					7	80	2	tr.		2		23,5
1		0,1	8	19														1						79	1,5	0,5		2		10,6
					†	†	†							†									†							0,1
			60	60	37	1,5								0,5										39	1			1		1,0
			8	8	55	5	1			2	2	0,5					tr.						20	85,5	6	0,5		6,5		10,3
2			2	5	40	10	3			1	3	0,5					1	tr.					35	93,5	1	0,5		1,5		12,0
			1	8	25	6	2			1	2						2	2					49	89	3	tr.		3		51,7
			1	11														8						84	4,5	tr.		4,5	0,5	11,0
		†			†	†																								0,1
		3		3	97	tr.																		97						3,1
		1	0,5	2	--98----																			98						23,5
		0,5	2	3	--97----																			97		tr.		tr.		16,2
		2	2	5,2	--93----		0,1											0,2						93,3	1			1	0,5	10,1
		1	2	15														0,1		4				79	5,2	0,2	0,1	5,5	0,5	4,8
					-100----																			100						0,4
					-100----																			100						1,1
			7	7	--90----																		0,5	90,5	2	0,5		2,5		2,2
		tr.	8	13	--76----		0,5											2				1	1,5	81	6	tr.		6		4,9
			8	19																				77	3	0,5	tr.	3,5	0,5	12,9

Table 25. Composition of Globigerina Oozes in the Central, Western and Northern

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite	pyrite	leucite and analcite
189III	2																																
	3																																
	4												tr.						tr.	tr.												2	
	5		†	†	†	†		tr.	tr.				tr.	tr.		tr.			tr.	tr.	tr.		tr.									4	
	6																															4	
189IV	2																																
	3																																
	4																															0,5	
	5		0,8	0,6	tr.	0,4		tr.	0,2	tr.			0,1	tr.		tr.			tr.	tr.	tr.		0,2			tr.						3	
	6																															3	
189V	2																																
	3																															0,5	
	4																															1	
	5		†	†	†	†		tr.	†	tr.			†	tr.		tr.			tr.	tr.	tr.		†			tr.						4	
	6																															3	
189A	1																																
	2																																tr.
	3																																
	4																															tr.	
	5		†	†	tr.	†		tr.	tr.				tr.			tr.			tr.	tr.			tr.									1	
	6																															2	
189B	2																																
	3							1																									
	4																		tr.													tr.	
	5		0,2	0,2	tr.	0,1		0,3	tr.	tr.			tr.			tr.			tr.	0,1			tr.					tr.				0,5	
	6																															1	
189C	2																																
	3							tr.	tr.																								
	4		0,1	0,1	tr.	tr.														0,1	tr.											0,5	
	5		5	4,5	0,2	2		0,5	1	0,2			0,6	tr.		0,8	0,1		0,2	0,4	0,1		1		tr.			0,1		tr.		6	
	6																															5	
188	1																																
	2																																
	3			tr.		tr.							tr.							tr.													
	4		0,2	0,4		0,2				0,2			0,3			0,2				0,5	0,2		0,3										
	5		1	2	0,1	1			0,5	1			1		tr.	1,2	0,2	tr.	tr.	0,3	0,2		0,6				0,1		tr.	0,2			
	6																																
193	1																																
	2																																
	3																																
	4		tr.	tr.						tr.									tr.	tr.													
	5	3	1	0,5				2	1	0,2			0,1	tr.		0,1	tr.		tr.				tr.										
	6																																
193E	1																																
	2																																
	3																																
	4							tr.																									
	5	3	2	0,3		0,1		2	1	0,2			0,2	0,1		0,2	tr.		tr.				tr.			tr.			tr.	tr.	0,3		0,1
	6																																
193D	1																																
	2																																
	3																																
	4	the mineralogical composition of 193D, 193C and 193B is practically the same as that of 193 E.																															
	5																																
	6																																
193C	1																																
	2																																
	3	fractions 1—4 contain no minerals fraction 5 contains few minerals.																															
	4																																
	5																																
	6																																
193B	1																																
	2																																
	3	fractions 1—4 contain no minerals fraction 5 contains few minerals.																															
	4																																
	5																																
	6																																
193A	1																																
	2																																
	3																																
	4		tr.					0,2	tr.																							tr.	
	5	3	2	tr.				2	1	0,2			0,1	tr.		0,1	tr.			tr.			tr.				tr.				0,2	0,5	0,2
	6																															1	

glauconite	manganese oxides	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Lamellibranches	Gastropods	Pteropods	Ostracode valves	Crinoid fragments	otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
			tr. 5 6 6	tr. 7 18 28	-100---- -100---- --90---- --70----		tr.			0,5							tr.	2					0,5 6	100 100 91 78 66	2 4 4,5	tr. tr. 0,5		2 4 5	1	0,5 0,8 1,8 4,2 11,3
		0,1	4 2 4	4,5 7,5 17	-100---- -100---- --91---- --56----		tr. 0,2				0,3						tr.	3				1 2,5	1 26	100 100 93 88 72	1,5 4 9	1 0,5 1	tr.	2,5 4,5 10	tr. 1	0,5 1,5 2,1 5,1 14,3
			tr. 3 2 4	0,5 4 11 25	-100---- --98---- --90---- --70----		tr. 0,1 0,1				0,2						tr.	1				0,9 2,7	0,5 1 10	100 98,5 92 84 67	1 3 4,8 6	1 0,2 1	tr.	1 4 5 7	tr. 1	0,4 0,8 1,6 4,5 11,9
		2 2 2 0,5	4 5 2 2	tr. 6 7 7 9,5	† -100---- --90---- --82---- --35----	†	0,1 0,5				tr. 0,5	tr.						tr. 3				10	0,8 42	100 90 83 91 80	tr. 3 5 1 8	1 5 0,5 1,8	tr. 0,2	tr. 4 10 1,5 10	0,5 0,5	0,07 1,0 2,2 1,9 7,2 18,7
		tr. tr.	15 15 22 9,5 6	15 16 22 11 12	--85---- --82---- --74---- --64----		tr. tr. 0,3				0,2						tr.	2				2,7	0,8 18	85 82 75 87 75	2 1 2 10	2 tr. 2,2	0,3	2 3 2 12,5	tr. 0,5	0,4 1,2 2,8 6,1 19,8
		tr. 0,1 tr.	4 12 3 5	4 13 25,7 30	97 94,5 84 61,4	1 0,5 1 0,6	tr. tr.											1				3	1 3,8	99 95 85 69,8 63	1 1 1 3 3,7	tr. 1 0,5 2	0,3	1 1 2 3,5 6	1 1	0,2 1,3 1,2 4,2 12,3
1 2 1		tr. 0,5 1 0,5	2 1 2 1	3 6 13,5 16,5	29 94 90 76 74,5	6 tr. 0,5 0,5 0,5	0,5 0,5 0,5 0,5				1 1 0,5						tr.	0,1					60 4,5 4,5 16 9,4	89 99 96,5 94 85,5 81	5 1 0,5 tr. 1 2	tr.		5 1 0,5 tr. 1 2	tr. 0,5	0,4 7,8 43,1 8,9 12,6 6,4
		tr.	tr. 0,5 1 1	tr. 0,5 9 11	-100---- -100---- --99,5--- --98---- --88----																	1		100 100 99,5 98 89 80	0,1 1,5 5,5	0,5 1,4 0,5 3,3	0,2	0,5 1,5 2 9	tr.	0,05 2,5 9,7 5,9 10,8 11,1
		0,2	0,2 0,5 1 1	0,2 0,5 11 9	98 100 99,4 --96---- --88----	2 0,1	tr.											tr. tr.						100 100 99,5 96 88 82	0,2 0,5 0,5 4	0,1 3 0,5 4	0,5	0,3 3,5 1 8,5	tr. 0,5	0,2 3,6 5,4 6,4 9,7 10,3
					† 99 --99,8-- --99----	tr.	1 0,1																	100 99,9		0,1		0,1		0,1 4,6 7,3 9,5 11,1 10,7
			0,2 1	0,2 1	† 99 --99,2--	† 1	tr.																	100 99,2	tr.	0,6		0,6		0,1 3,8 14,9 6,9 13,3 10,8
			0,2 1	0,2 1	100 100 --99----	tr.	0,2																	100 100 99,2	0,2	0,4		0,6		0,3 3,3 4,3 14,3 13,5 11,0
			0,8 1 1	tr. 1 10,5 10	† 99 --99,9-- --96---- --87----	† 1	tr. tr.											tr.						100 99,9 96 87 84	tr. 0,1 1,7 3	0,1 2,9 0,6 2,5		0,1 3 2,3 5,5	tr. 0,2 0,5	0,1 1,2 3,4 6,0 8,8 13,6

Table 25. Composition of Globigerina Oozes in the Central, Western and Northern

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	radiolarite	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	tremolite	actinolite	glaucophane	chloritoid	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	staurolite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite	pyrite	leucite and analcite
201	2																																
	3		tr.			tr.		1	tr.					tr.						0,2												1	
	4			tr.				0,5												tr.												1	
	5		3,5	1		1		12	0,1	0,1			0,1	tr.	tr.	tr.				0,3			0,1	tr.	tr.	tr.	tr.	tr.		tr.	tr.	1	
	6																															1	
248	2																																
	3	tr.																															
	4		tr.																														
	5	0,5	1,5	0,5		tr.		2	0,2	0,1			0,1			tr.				0,5			0,1		tr.			tr.			0,1		
	6																																
239		†	†					†	†	†																					†		
250	1—5		†	†	†	†		tr.	†	†			†			†			†	†	†		†		†	†	†	tr.	tr.		†		
	6																																
233	1							†																									
	2							3																									
	3	2	2					15																									
	4	2	2					10	tr.	tr.									tr.														
	5	3,5	3	4		3		12	0,5	1,2			0,2			0,2			2	3	0,3	tr.	0,3		tr.	0,1	0,1						
	6																																
320	1	18	4					54																									
	2	2	2					9																									
	3	2	2					3		0,4										tr.											0,1		
	4	3	2					4	0,1	0,3																					tr.		
	5	7	6					5	0,5	1																					tr.		
	6																																
242	2	3																															
	3	7	1					2,5	0,2	0,1		0,1																					
	4	12	3					5	0,5	0,3		tr.	0,1								0,1												
	5	14	4					6	1	1		tr.	0,1						tr.		1	tr.											
	6																																
299	1—5	14	12					0,3	10	0,5		0,1	1	0,2		tr.			0,1		2		tr.								1		
	6																																
290	1—5	6	16					5	2	1		0,1	0,5	0,1					0,1		0,3										0,3		
	6																																
286	P	†	†				†	†	†	†			†	†		†				†	†		†			†							
285	1							†																									
	2							tr.																									
	3		tr.					tr.																									
	4		0,4					3	tr.	tr.																							
	5	5	8	1	0,5	0,5		10	3	1			1,5	0,2		0,5			0,2		1		0,8								0,8		
	6																																
283	1—5	†	†	†				†	†	†			†	†																			
	6																				†										†		
338	1																																
	2																																
	3	1						2																									
	4	9	0,5					8	tr.	tr.			tr.																				
	5	24	15					15	1	2		tr.	1	tr.		tr.					0,1	tr.	tr.								1		
	6																																
335	2																																
	3							tr.																									
	4	3	1					5	tr.	tr.																							
	5	7	8	0,5				29	0,5	1,5			0,5			0,7			0,5		0,5	tr.	0,2								2		
	6																																
64	1																																
	2																																
	3																																
	4	1	0,3					0,3					tr.						tr.														
	5	7	3					8	0,1	tr.			3	0,2								tr.									0,1	0,5	
	6																															1	
65	2																																
	3																																
	4																																
	5	5	6	0,2		0,2		6	0,5	0,3			6	0,5					0,3			0,1	0,1		0,2	tr.	tr.		tr.		0,3	tr.	
	6																															tr.	
66	2																																
	3							0,1											0,6	0,3													
	4	0,1	0,2					0,7		tr.			tr.						0,3	1													
	5	4	7	0,3		0,3		2	0,1	tr.			2	0,3					0,1	0,1		0,1	0,1		tr.							0,1	
	6																															0,5	

part of the Eastern Netherlands Indian Archipelago.

glauconite	manganese oxides	limonitic casts	clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	shell fragments	Lamellibranches	Gastropods	Pteropods	Ostracode valves	Crinoid fragments	otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
					†	†	†					†													†					0,05
			0,8	3	--90--	----	1																	91	5	1		6	tr.	0,7
		tr.	1	2,5	--90--	----	tr.																	90	2	5		7	0,5	1,0
		tr.	2	21,5	69,5	0,5																		70	7	1	tr.	8	0,5	4,0
			2	23																				61	11	4,3	0,2	15,5	0,5	12,2
					99,7	0,3																		100						2,3
			1	1	--98--	----																		98		1		1		4,4
			3	3	--92--	----																		92		5		5		4,8
			3	8,5	--90--	----																		90	0,5	1		1,5	tr.	7,0
			1	13																				80	2	4	0,5	6,5	0,5	13,3
	†				†	†																								
		0,5	0,5	31	--67--	----	0,2																	67,2	0,5	1		1,5	0,3	17,3
			1	46																				50	2	2		4	tr.	13,4
					†																									0,02
				5	96	1																		97						2,3
				19	--80--	----	0,5																	80,5		0,5		0,5		9,7
			2	16	--80--	----																		90		4		4		5,3
			1	34,5	--64--	----																0,3		64,3	1	0,2		1,2		12,4
			0,5	40																				55	3	1,6	0,2	4,8	0,2	16,2
				76	--24--	----																		24						0,3
			1	14	--86--	----																		86						6,4
			0,5	8	--92--	----	tr.																	92						14,9
			0,5	9,9	--90--	----	tr.																	90	tr.	0,1		0,1		17,1
			0,5	20	--80--	----	tr.															tr.		80	tr.	tr.		tr.		18,5
				15																				82	1	2		3		12,6
				3	95	2																		97						0,3
			1,1	12	--87--	----																		87	0,8	0,2		1		1,1
			5	26	--63--	----																		63	4	7		11		2,8
			3	30	--63--	----	tr.																	63	4	3		7		7,3
				15																				69	3	12	1	16		13,1
	tr.	0,5		41,7	50	1	0,1															0,1	6	57,2	1	0,1		1,1		76,7
				67														0,1						30	2,4	0,1	tr.	2,5	0,5	7,2
		0,5		32	40	3	0,3				1	0,2						0,5				1	12	58	9,5	0,5		10		69,1
				60														1						36	3	0,9	0,1	4		13,8
		†			†	†																								
					†	†																								0,15
				tr.	100		tr.																	100						3,8
			tr.	tr.	-100--	----																		100						9,2
			1	4,4	--95--	----	0,2																	95,2	0,1	0,3		0,4		8,8
			6	40	--58--	----																		58	1	1		2		25,1
			6	46																				51	2	1		3		14,2
				6	68	2	0,5			1	2			0,1	0,1		0,3						14	88	6			6		92,0
		0,1		35														2						61	3	0,5	tr.	3,5	0,5	2,8
					-100--	----																		100						0,1
					--97--	----	1																	98	2			2		2,4
			1	4	--84--	----																		84	5	7		12		6,1
			4	21,5	--70--	----																		70	2	6	0,5	8,5		3,8
			1	60,1	--36,3--	----												0,1						36,4	3	0,5	tr.	3,5		29,0
			3	59														0,1						33,5	4	2	1	7	0,5	22,1
					100																			100						0,3
				tr.	100	tr.																		100		tr.		tr.		1,1
			2	11	--82--	----												tr.						82	tr.	7		7	tr.	2,2
			5	56	--42--	----																		42	1	1		2	tr.	7,1
			2	55																				35	6	3	0,5	9,5	0,5	15,5
			†		†																									0,01
			60	60	--40--	----																		40						1,4
			29	29	--70--	----	tr.																	70	1			1		4,1
			25	26,6	--70--	----	0,1																0,3	70,4	1	2		3		5,5
			8	30	--60--	----	0,3											2				2	0,7	65	4	1		5		13,6
			3	24														3			0,1			64	8	2,5	0,5	11	1	20,6
					100									tr.										100						2,2
					100	tr.																		100						7,2
			0,6	0,6	99	tr.																	0,3	99,3	0,1			0,1		3,6
		0,3	1	27	72	tr.												0,2					0,2	72,4	0,3	tr.		0,3	0,3	9,8
		0,2	2	32,5														1						66	1	tr.		1	0,5	15,4
					99	tr.																		99	1			1		0,5
			tr.	1	67	7	3	2			1,5	0,3					2	0,2					12	95	4			4		6,0
		0,1	0,5	3	55	6	3				0,7	0,1					2	0,2					29	96	1	tr.		1		5,0
		0,5		17	--53--	----	1										1	3					22	80	3	tr.		3		15,0
				23,5														3			tr.			63	12	1	tr.	13	0,5	11,8

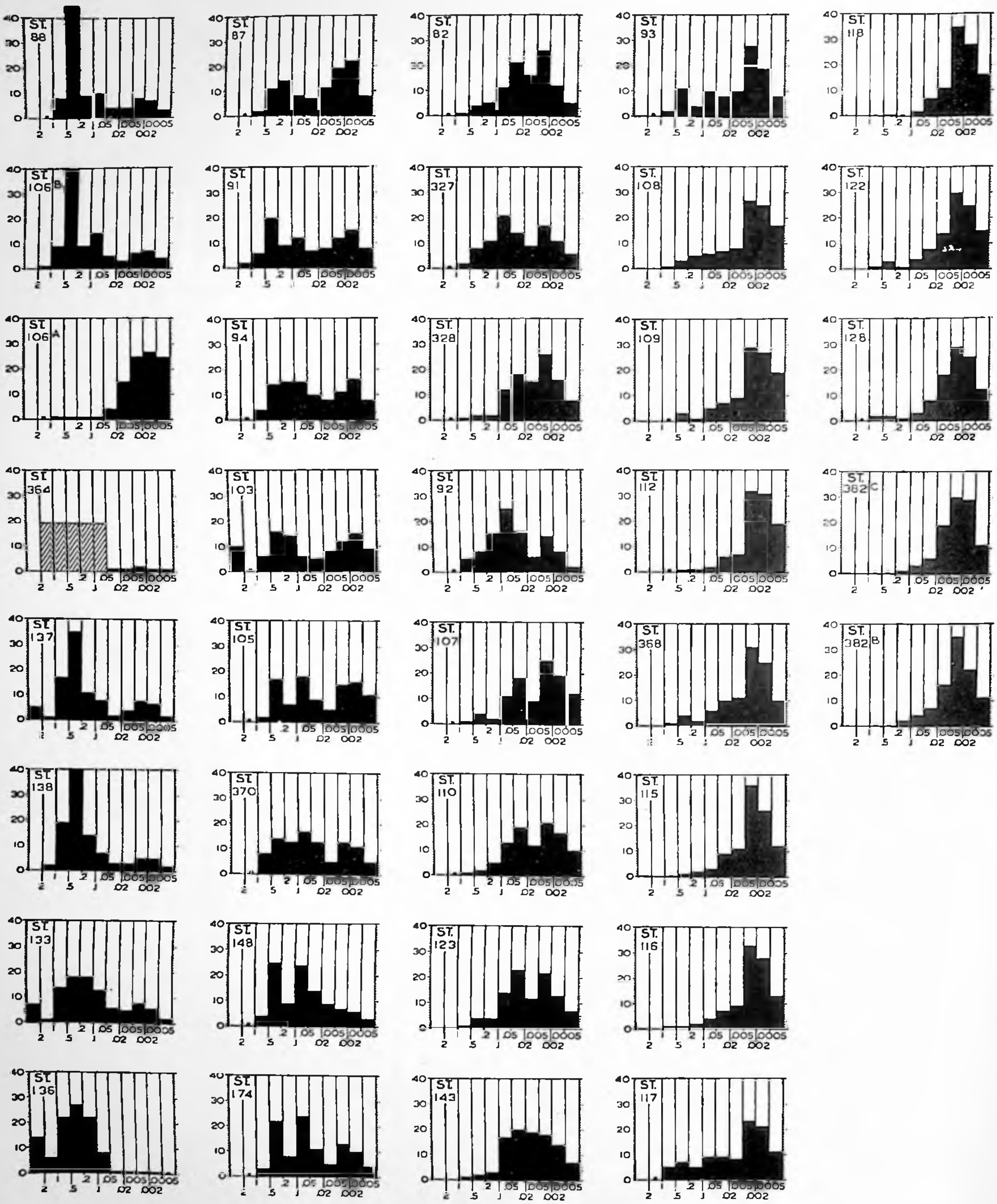


Fig. 24. Mechanical Analyses of Globigerina Oozes in the Eastern and South-Eastern part of the Netherlands Indian Archipelago.

The first group, that is samples 88, 106B, 364, 137, 138, 133, 136, 29, 188, 200, 283, 290 and 299 embraces coarse sandy Globigerina Oozes in which fraction 0,2—0,5 mm often forms the chief component. This fraction here consists chiefly of unbroken shells of pelagic Foraminifera, especially those belonging to the family of the Globigerinidae. The pelagic Globorotalidae are usually of larger size, they form the principal component of fraction 0,5—1 mm and occur also in fraction 1—2 mm; the Globorotalidae are only seldom found in the fractions smaller than 0,5 mm. The Globigerinidae, on the other hand, often still form the chief component of the fine sand fractions (200—20 μ) of the Globigerina Oozes; they are not entirely absent in fraction 0,5—1 mm, but are seldom of larger size.

The mechanical diagrams of samples 88, 106B, 364, 137, 138 (photo 11), 29 and 188 are characteristic for the typical Globigerina Oozes of the E. I. Archipelago. In sediment 29 (photo 12) the Globigerinidae are of smaller mean size than in the other samples; yet the shells of the Foraminifera in this sample, just as in the other Globigerina Oozes, are to a great extent complete and sound.

The sediments of the first group lie either upon submarine ridges or near the edges of shelves. They have a relatively high calcium carbonate content.

Samples 133 and 136 show a somewhat different mechanical composition; the fine sand fractions are more strongly represented owing to the presence of a great deal of limestone detritus of 50—200 μ size.

The deviation in the relative lime content of samples 290 and 299 (photo 13) is caused by sandy volcanic material, which does not alter the scheme of the mechanical composition of these samples, but only diminishes the relative calcium carbonate content (see map III).

The second group of Globigerina Oozes, including the samples 87, 91, 92, 94, 103, 105, 370, 148 (photo 14), 174, 34 (photo 15), 185, 320, 338 and 285 give mechanical diagrams which contain coarse sand, as well as fine sand and silt, as well as clay. These diagrams often have peaks in fractions 50—100 μ and 0,2—0,5 mm. Where there is a peak in fractions 0,2—0,5 mm the Foraminifera content of this fraction varies between 60 and 100%. The peak in fraction 0,2—0,5 mm in these sediments, as in the first group, is caused by the frequent predominance of these measurements in the pelagic Foraminifera. The peak in fraction 50—100 μ in samples 94, 105, 370 and 320 is also caused by the high content of Globigerinidae; in samples 91, 92, 148, 174, 34, 185, 338, and 285 the high content of recent-volcanic or terrigenous detritus amongst which limestone and coral rock detritus should be included, are the chief cause of these peaks in the fine sand fractions.

These more composite mechanical diagrams, therefore, vary both with the diameter of the Foraminifera and with that of the recent-volcanic and terrigenous material. The relative calcium carbonate content in this composite material is naturally varied.

The third group of Globigerina Oozes consists principally of fine sand and clay, the mechanical diagram often showing a peak in fraction 20—50 μ, or sometimes in 50—100 μ. To this the sediments 82, 327, 328, 107, 110, 374 (photo 16), 123, 143, 64, 65 (photo 17), 66, 242 and 233 belong. Of these samples 374B, 65, 66 and 233 have minor peaks in the coarse sand fraction 0,2—0,5 mm, which again is due to a somewhat larger content of Foraminifera of this size.

The peak in fraction 20—50 μ or the fraction 50—100 μ in the Globigerina Oozes 107, 110, 123, 143, 64 and 242 is principally caused by the high content of broken Foraminifera shells, moreover in samples 110, 123, 143 and 64 in these fractions there is an increasing content of calcite and of microcrystalline calcite aggregates. In sediments 82 and 66 it is the high content of limestone and of coral rock detritus especially which caused the peaks in the above fractions. In the Globigerina Oozes 327, 328, 374, 65 and 233 it is the terrigenous admixture of 20—100 μ particularly which are responsible for the peaks in these fractions, while in sample 374 moreover the effect is felt of a higher content of broken Foraminifera shells.

The relative calcium carbonate content of these samples varies, just as in the Globigerina Oozes of the second group.

The fourth group is characterised by a high content of the finest fractions. To this the Globigerina Oozes 93, 108, 109, 112, 368, 115, 116, 117, 118 (photo 21), 122, 128, 382 (photo 19), 201, 248, 250, 335, 193 and most of the sampled layers of sediments 189 (photo 20) and 193 belong.

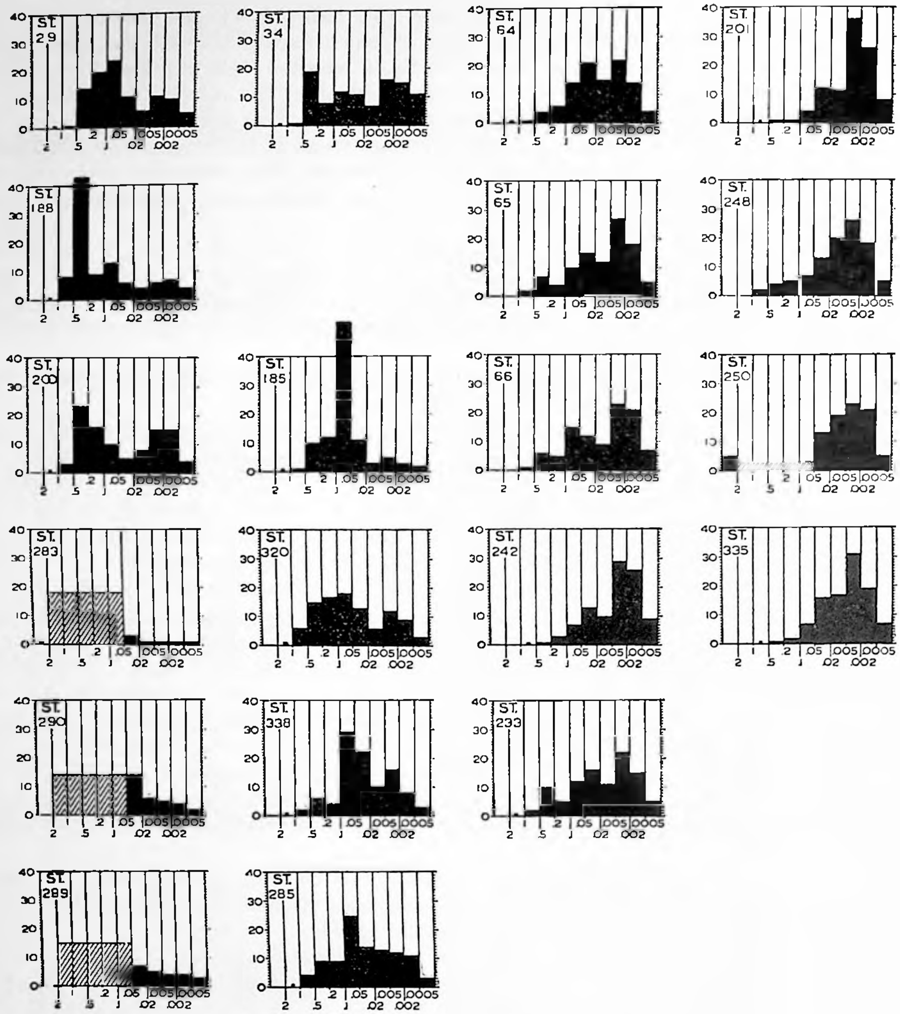


Fig. 25. Mechanical Analyses of Globigerina Oozes in the Central, Western and Northern part of the Eastern Netherlands Indian Archipelago.

These samples have a low to very low mineral content of the sand fractions, the terrigenous components consist chiefly of clay. In habitus they may be compared with the Terrigenous Muds (see photo 7 & 8). Small contents of detrital lime are found in sediments 112, 117 and 118, only some of the section samples of 189 contain larger amounts of detrital lime, in 189A there is so much that it effects the mechanical diagram, causing a peak in fraction 20—50 μ. Only samples 93 (photo 18), 368, 117, 193 and 193C remind of the typical diagram for Globigerina Ooze, having a distinct peak in fraction 0,2—0,5 mm; the Foraminifera content of these peak fractions varies between 88% and 99%.

The Foraminifera shells of the Globigerina Oozes of this fourth group are partially or even entirely broken.

The mechanical composition of the Globigerina Oozes of the fourth group, thus, indicates a combination of fine terrigenous material with broken Foraminifera shells.

The relative calcium carbonate content of these samples varies to some extent with the content of terrigenous material; extremely high lime-contents do not occur in this group, as might be expected.

The minerals of the Globigerina Oozes have been treated already. The secondary minerals in these deposits, of which glauconite is the principle, will be discussed with the secondary minerals of the other deep-sea sediments in chapter VIII.

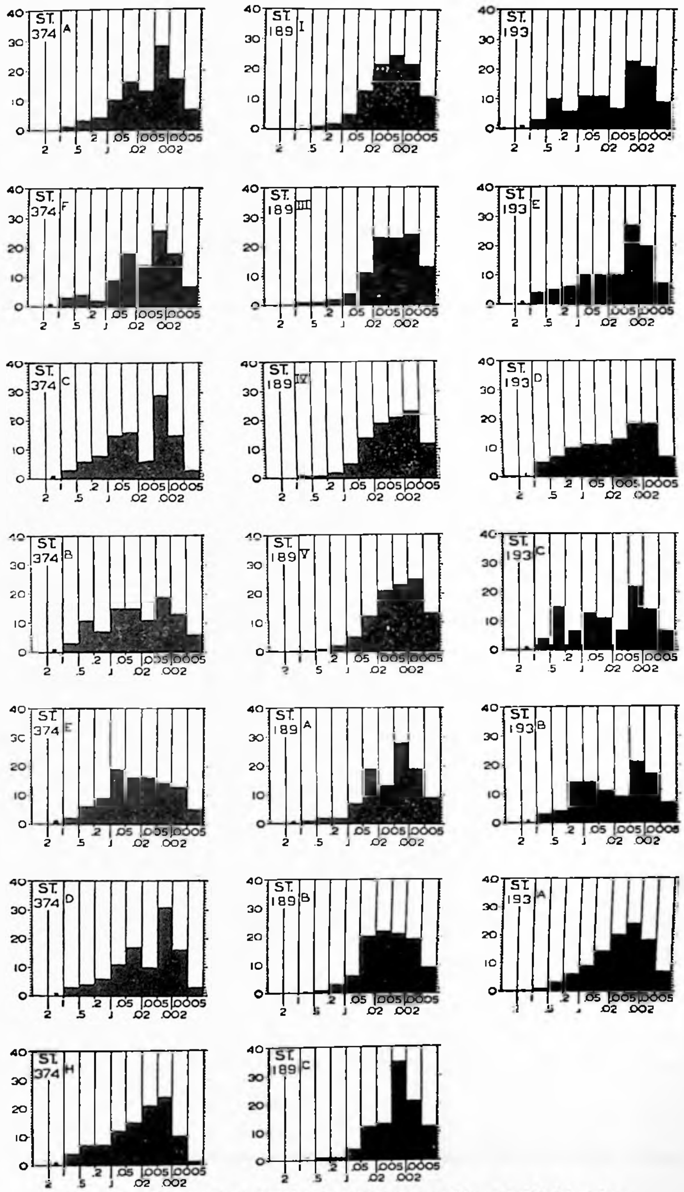


Fig. 26. Mechanical Analyses of some profiles of Globigerina Oozes in the Eastern Netherlands Indian Archipelago.

It should here again be pointed out that the defnition of Globigerina Ooze given by Böggild (8) is different to the definition given by the Challenger-expedition. In accordance with Böggild in the Snellius-expedition Globigerina Ooze means sediment which has a $CaCO_3$ content of more than 30%, of which the greatest part consists of pelagic Foraminifera, while the Globigerina Ooze of the Challenger-expedition contained 30% chiefly pelagic Foraminifera. If the latter definition was made use of the extent of Globigerina Ooze would have to be restricted on map I, mostly in favour of Terrigenous Muds. Sediments 82, 328, 87, 108, 109, 110, 112, 115, 116, 118, 374A, 128, 382C, 143 and 189 would then be given as Terrigenous Muds. Sediments 242 and 335 would not be given as Globigerina Ooze in the area of the Terrigenous + Volcanic Muds, and sediments 66 and 201 would probably be reckoned as Coral Muds. This, generally speaking, would only mean a small restriction of the areas of Globigerina Ooze; only to the east of the island of Jamdena, in this case, a larger area would be marked as Terrigenous Mud rich in limestone detritus.

TABLE 26. Composition of Coral Muds, Coral

No.	Fr.	rock particles	plagioclase I	plagioclase II	orthoclase and sanidine	quartz	volcanic glass	monoclinic pyroxene	rhombic pyroxene	enstatite-augite	olivine	green hornblende	red hornblende	actinolite	biotite	muscovite	chlorite and serpentine	apatite	epidote and zoisite	zircon	tourmaline	garnet	titanite	rutile and brookite	chromite and picotite	magnetite and ilmenite	pyrite	analcite	glauconite	limonitic casts
67	2																													
	3														tr.	2														
	4		tr.	0,1		tr.	tr.																							
	5	1	2	2		1	2	tr.	tr.			0,3	tr.	tr.	tr.	tr.			tr.	tr.	tr.									
	6																										0,2			
60	1					tr.																								
	2																												tr.	
	3	tr.	tr.	tr.		tr.		tr.																						
	4	tr.	†	tr.		tr.		†	tr.			tr.					tr.		tr.							tr.				tr.
	5	tr.	†	tr.		tr.		tr.	tr.			†	tr.				tr.	tr.	tr.							tr.				tr.
	6																													
59	S	12	14				5	0,2	0,2			6	0,3				0,5	tr.								0,3			0,5	
63	S									-25-																	1			
73	1																													
	2	tr.					tr.																							
	3			0,5																									0,5	
	4	tr.	0,4	4		2									tr.	tr.														
	5	tr.	1	3,3		2	tr.					0,3	tr.	0,2	tr.	tr.			tr.											
	6																										0,2			
45	1																													
	2																												5	
	3					tr.									tr.														1	
	4		0,1	0,4		0,2											0,3												3	
	5		1	4		3	tr.	tr.	0,1			0,2	tr.	0,1	tr.	0,1	0,5		0,1	0,1	tr.	tr.	tr.	tr.	tr.	0,1	tr.		1	0,3
	6																										1			
51	S	†	†					†																						
346	P	†	†			†		†	†			†	tr.													†				
269	1																													
	2																													
	3		tr.																											2
	4	2	3				0,5	0,3	tr.			0,1			0,1		2													2
	5	20	21	3	0,5	0,2	0,5	5	0,2	1		5,5	0,5	5	0,1		10	1	2	tr.			tr.			1				2
	6																													0,5
352	S		†						tr.			†					†													
206	1																													
	2																													
	3																													
	4	0,3	0,2	0,3		0,1										0,1														
	5	0,2	0,5	0,2	tr.	0,1	tr.	tr.				0,1		0,1	tr.	tr.										0,1				0,5
	6																													
199	P	†	†				tr.	†				tr.			tr.													tr.		
182L	1	2																												
	2	5	1					0,5							0,5															
	3	8	4				0,5	1							0,5															
	4	9	8				0,5	4	tr.		1	tr.			0,3			0,2								3				
	5	22	12				1	8			0,3	tr.			0,1			0,5								3				
	6																													
165	P	1	2				24	0,3							0,6															
157	S	†		†		†	†		†					†	†	†	†		†			†								
124	1																													
	2																													
	3																													
	4														tr.															
	5		tr.	tr.		tr.									tr.	tr.											tr.			
	6																										0,2			
129	2																													
	3																													
	4																										tr.			
	5																										0,1			
	6			tr.		tr.																					1			

Sands and Shallow Water Deposit.

clay casts	total amount of minerals	pelagic Foraminifera	benthonic Foraminifera	Echinoderm fragments	Shell fragments	Lamellibranches	Gastropods	Pteropods	Ostracode valves	Otoliths of fish	Bryozoa	Corals	Alcyonarian spicules	calcareous Sponges	Coccolithes	Discoasteridae	calcite and dolomite rhomboedra	calcite and dolomite	undefined calcareous debri	carbonate of lime	Sponge spicules	Radiolaria	Diatoms	total amount of siliceous organisms	organic matter	percentage fractions of sample
		67	4	1	2					3		3							17	97	3			3		0,2
	2	43	2	2			0,7	3	1				0,3	tr.					25	77	20	1		21		2,8
tr.	0,3	33	5	2				4					2	0,1					44,6	90,7	3	6	tr.	9		7,4
	8,5	--20----		2				1					1	10					51	85	6	0,5		6,5		23,9
	6													12						85	8	0,7	tr.	8,7	0,3	19,3
			†	†	†	†	†			†	†	†														27,1
			†								†		tr.	tr.					†							26,4
		tr.	†		tr.	tr.	tr.	tr.					†						†							41,3
tr.		†	†					tr.					†						†		†					2,1
		†	†					tr.					†	†					†		†					1,7
	†	†	†											†					†		†					0,3
	39	7	3	2				1	tr.			tr.	2	2				5	36	58	3			3		
	26	12	5	0,5										20				2	22	61,5	10	2	0,5	12,5		
5	5		5	3	2			tr.		10									60	80	15			15	tr.	0,5
4	4	47	4	3				1	.tr.	1	6								32	94	2			2		3,8
1	2	63	4	3			2	2	0,5				0,5						18	93	5			5		30,0
0,5	7	32	9	2				2						tr.					43	88	5			5		11,8
0,1	7	15	1	1				1						10					61	89	4	tr.		4		27,1
	9													11		tr.				77	12	1	tr.	13	1	7,9
			12				4					40							44	100						0,3
	5	18	5	0,5			tr.					5,5							63	92	2			2	1	1,2
1	2	35	3	0,5				0,3	tr.				0,1	0,1					56	95	3			3		9,7
1	5	40	2	0,4				0,5					tr.	0,1					49	92	2	1		3		5,8
1	11,7	32	5	0,5				1						2					42,5	83	4	1		5	0,3	11,8
1	22,5													3			0,1			70	6	1	tr.	7	0,5	9,7
	±15		†	†			†	†		†	†	†								±85						
												†														
		75		4	1						5								15	100						1,6
		88	3	1				1		tr.	1								6	100						17,1
	2	84	3	0,5				0,5											10	98						32,1
	10	54	2,5	0,5				0,5					0,3					0,2	32	90	tr.			tr.		3,3
	78,5	--16----												tr.					5	21	0,5			0,5		6,9
	85,5															tr.				14	0,5			0,5		9,8
		†	†				†	†			†	†	tr.						†							
		3	2	2			8	2		2	25	45							11	100						7,9
		72	1	1			1	1					tr.						23	99	1			1		14,7
		85	0,5	0,5			1	1	0,5				0,5						10	99	1			1		42,3
	1	--65----		0,5				0,5											32	98	1			1		19,7
	2	--50----		0,5				0,5						2					43	96	2	tr.		2		8,8
	2													1		tr.	1			95	2,4	0,5	0,1	3		1,0
		†	†			†						†									†					
	2		25		2		2			1	40	5							23	98						8,2
	7	2	13	0,5				1	1		10		1,5						64	93						37,7
	14	3	14	1				tr.					4						64	86						48,8
	26	1	8	1									7	1					55	73	1			1		2,7
	47	---3----											4	1					44	52	1			1		0,3
	30													2						66	4			4		0,3
	28	12	6				1	1,5				tr.		0,5					47	68	3,5	0,5		4		
		†	†			†	†	†			†							†								
			†		†							†							†							0,1
3	3	82	7	3								4								96	1			1		0,8
4	4	--36----		5			4	3				2	3	1					37	91	5			5		5,3
6	6	--45----		2			4	4				1	1	1					35	93	1			1		6,0
4	4	--18----		1			1	1					2	10					62	95	1			1		28,0
3	5													10			0,5			92	2,5	0,5		3		16,9
		80	5	5								2							7	99	1			1		0,4
tr.	tr.	55	5	5			4	10	0,5			5	0,5	1					12	98	2			2		1,1
tr.	tr.	36	6	2			4	10				3	2	1				tr.	32	96	3	0,5		3,5	0,5	3,4
0,9	1	--20----		1				2					2	30				2	39	96	3	tr.		3		13,2
tr.	1													15	tr	tr.	tr.			95	3	0,5		3,5	0,5	27,9

4. CORAL MUD, CORAL SAND AND SHALLOW WATER DEPOSIT.

Coral Sand and Mud are derived from coral reefs and banks. Coral reefs are attacked by boring organisms and by the breakers, forming Coral Sand and Mud, which is deposited at a greater or less distance from the reefs according to the grain-size. Fine Coral Mud, therefore, may be found at great depths, according to Andrée (2) down to 3000 m. According as the distance from the coral reef and the depth at which the sediment has been deposited increase the pelagic Foraminifera may have a larger share in the sediment, till it gradually becomes a Globigerina Ooze. On our Plate I the transition from Coral Mud to Globigerina Ooze is given by yellow and green stripes in distinction from the true Coral Sand and Mud which is coloured yellow. Coral Sand and Mud consist of detritus of coral rock, calcareous algae, Bryozoa and whole or broken Echinoidea shells, Alcyonides, benthonic and pelagic Foraminifera etc. in greatly varying quantities. If coral particles are absent, as at St. 157 the sediment is indicated as Shallow Water Deposit.

Distribution.

On Plate I Coral Sand and Mud are only marked where this sediment has been found either on the Snellius-expedition or one of the earlier expeditions. Considering the great extent of the coral banks and reefs in the eastern E.I. Archipelago, these deposits certainly occupy more space than has been shown by the deep-sea researches so far carried out. They are found chiefly by the Soeloe Archipelago, along the edges of the Soenda shelf and the Sahoel shelf, in the Halmaheira sea, near the Paternoster, Postiljon and Toekang besi islands and locally in smaller amounts near the coasts of large and small islands.

The mechanical composition of Coral Sands and Muds.

In table 26 and fig. 27 the composition and the mechanical analyses of these deposits are represented.

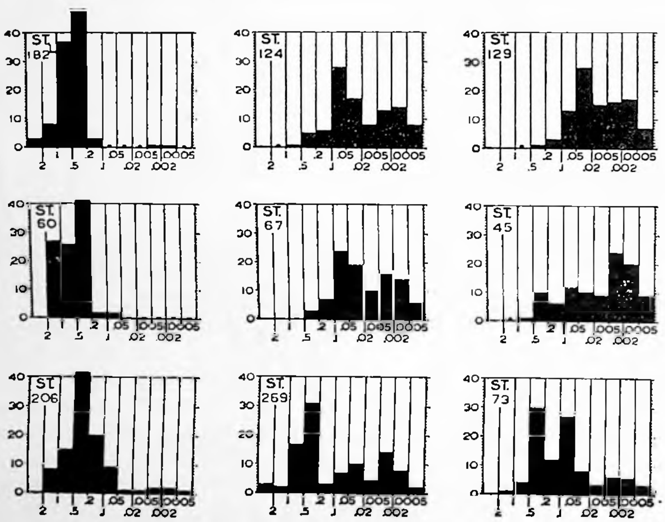


Fig. 27. Mechanical Analyses of Coral Muds and Sands.

Dr. Kuenen reports that besides the samples given for examination, coarse coral particles were found at stations 372, 289, 295 and 298 (see table 2) while he describes Coral Sand from stations 139 and 351.

According to the mechanical composition four groups may be distinguished.

1. very coarse coral particles, sometimes covered by a film of manganese, are found only at places where there are strong bottom currents, that is, at stations 298, 295 (photo 1), 289, 352 and 372. The depth of these stations varies between 800 and 1600 m.

2. coarse Coral Sand is found in the immediate vicinity of the coral reefs. In this category are the deposits at stations 60, 51 (photo 22), 346, 351 (photo 23), 199, 182^{L} (photo 24) and 139. Sediment 157, which consists of benthonic organisms and coarse sandy terrigenous material, is of similar mechanical composition. The depth of these stations varies from 80 to 800 m.

3. sediments 59, 73 (photo 25), 269 and 206 consist principally of medium-grained sand. The three last sediments form the transition from Coral Sand to Globigerina Ooze.

4. the Coral Muds 67, 45, 165, 124 and 129 (photo 26) consist of fine sand and mud. These sediments were found at depths from 380—1980 m.

Sediment 63, included in table 26, only a trace of which was raised, probably lies at the boundary between Coral Mud and Terrigenous Mud. It contains calcareous debris and many calcareous Sponges, but distinct coral particles could not be detected.

The Globigerina Ooze 66 contains a considerable amount of calcareous debris somewhat similar to that of the Coral Mud 67. St. 66, therefore, probably lies in a transition area from Coral Mud to Globigerina Ooze; in sample 66, however, as in 63 no distinct coral particles could be detected.

The variation in composition of the Coral Sands and Muds comes out clearly in table 26. The mineral content of these sediments is usually low, by the coast alone there are somewhat higher contents of terrigenous detritus, especially in samples 59, 63, 45 and 269, while 165 and 182^L contain Tambora ash.

Benthonic Foraminifera are more conspicuous in the Coral Sands 182^L, 60, 51, 352 and in sediment 157.

Bryozoa form an important contribution to the sands 60, 182^L and 206.

Calcareous Sponges occur in samples 63, 67, 73, 124 and 129 in considerable quantities.

The lime-content of the Coral Sands and Muds has been discussed above in the treatment of the calcium carbonate content of the sediments. The organisms of these sediments will be dealt with in chap. VIII.

5. HARD BOTTOM AND COARSE DEPOSITS

From 70 stations explored by the Snellius-expedition Dr. Kuenen reports no sample, or only a sporadic small one, or only pebbles and gravel, due in a great number of cases to the effect of strong to very strong bottom currents at these stations.

a. Very strong currents can prevent a sedimentary covering of any kind on the sea-floor. The sampling apparatus is then dinted by hitting on the hard bottom, while nothing is brought up. This occurred at stations 70, 113, 156, 270, 297, 321 and 357 (see table 2). Hard bottom was thus found both on sills, as in the Siboetoe straits (70), east of the island of Sermata (113), in the connection between the Indian Ocean and the Timor sea (156), in the straits of Kawio (297) and by the Banda islands (357), as well as along the walls of deep basins, like the Mindanao trough (270) and the Weber deep (321); the incline at St. 270 is 11° so that it may cause the slipping away of any sediment that might form.

Earlier expeditions also reported the presence of hard rock bottoms:

1. in the straits of Lombok to a depth of 312 m, here it is assumed to be due to tidal currents.
2. at the edge of the Batjan basin at station C. 196 at 1500 m depth.

b. At various other stations no sample was raised although the sampling went quite normally, so that there is no indication of a hard bottom, although the absence of a recent sedimentary covering is demonstrated at these stations. These stations are therefore also marked on map I by black rectangles. This applies to the Sawoe strait (134 and 135), the Dao strait (140), stations 149 and 168 east and north of the volcanic island Sangean Api, St. 164 in the Banda sea to the north of Alor, St. 196 north of the volcanic island Paloeweh, St. 219 near the south coast of Sanana, the Lifamatola straits (224, 226), St. 240 by the southern Siboga ridge along the edge of the Central Banda sea, the Kawio straits (300) and the strait west of the Boo islands (354).

c. Strong bottom currents are certainly running where only pebbles or gravel were brought up, seldom mixed with a little sand and partly covered by a film of manganese.

Sometimes the pebbles were formed by fragments of a hardened sea floor which had worked loose:

at St. 288, lying on the sill between the Mindanao trough and the Morotai basin, hard clay was raised,

at St. 323 „marl with a large number of small concretions" was found,

at St. 135a 2—3 cm large fragments of Globigerina-bearing marl and fragments of weathered rock were met with,

the „hard bottom" 156 mentioned under *a* also was bumped loose and proved to consist of yellow marley limestone.

Moreover pebbles and gravel were found:

south of the small island of Miangas (295), in the Kawio straits (298, 299), in the Siaoe strait (289), east of the Minahassa (339, 340), in the strait of Obi (81), on the sill between S.E. Halmaheira and Gebée (352), east of Obi Major (83), in the Manipa strait (256, 230), from the northern part of the Manipa strait Tydeman also reports from 3 places only gravel and coarse sand (Siboga-expedition), further by the south and east coasts of Boeroe (252, 211, 222), by the south east coast of Taliaboe (217), near the Siboetoe strait (69), by the coast of Borneo in the Makassar strait (42), by the north coast of the volcanic island of Paloeweh (195, 195^L), on the sill between Timor and the islet of Kambing (162) and by South Terbang (372).

In the straits between the N.E. point of Celebes and the island of Biaroe only a smooth boulder was found by the Siboga-expedition.

The Challenger-expedition found only stones and gravel by the S.W. coast of Zamboanga (C. 201).

d. Finally it is assumed that where only a „trace sand" was found a fairly strong current may run.

This was the case at:

St. 267 lying at a shallow part of the submarine ridge to the south of East Mindanao.

St. 294 on the sill between the Mindanao trough and the Sangih trough. „Marl and sand" are reported from this station.

St. 346 by the west coast of North Halmaheira.

St. 223 and 225 in the Lifamatola straits.

St. 207 east of the island of Wangi-Wangi.

St. 150 in the Sape strait.

St. 130 by the sill between the Indian Ocean and the Timor trough.

For 20 stations no sufficient conclusions can be drawn concerning the condition of the sea-floor, these are the stations where „wire broken", „sounding stopped", „jaws not closed" and „soft bottom, no sample", is reported. From stations 90, 127, 198 and 277 it appears from the description that there is a sediment at these places; amongst the other stations where no sample was obtained because the jaws did not close, undoubtedly there would be some more without a sedimentary covering.

To summarise, it appears, therefore, that the very strong bottom currents (hard bottom or no sample and film of manganese) run over the sills between the Pacific Ocean and the Sangih trough (St. 295, 294) and between the Pacific Ocean and the Mindanao trough (St. 288).

The currents continue on the one hand through the Sangih trough. On the sills of the Kawio straits, the Siaoe strait and the Biaro strait, between the Sangih trough and the Celebes sea they again form strong bottom currents. In the Celebes sea they show their influence upon the distribution of the recent-volcanic material of the Sangih volcanoes and on the calcium carbonate content of the sediments. In the northern part of the Makassar strait they still show their presence at St. 42.

The well oxygenated bottom currents of the Pacific Ocean continue, on the other hand, along the coasts of Halmaheira and the Minahassa (St. 340, 339), through the Lifamatola straits (St. 81, 224, 225 and 226), south of Sanana and through the Manipa strait (St. 256). In the northern Banda sea they still effect the lime content of the sediments. In the Banda sea, along the coasts of Taliaboe, Boeroe and by Toekang Besi strong currents run. In the central Banda sea very strong currents run (St. 240, 357, 321); and at St. 239 manganese concretions were found in the Globigerina Ooze, while at St. 235 manganese secretions were found in the sediment. In the northern Ceram sea manganese concretions were again found at St. 355 of the Snellius-expedition and at St. 177 of the Siboga-expedition.

In the southern Banda sea and the Weber deep there are no signs of the effect of currents upon the composition of the sediments, at any rate it is not shown by the lime content of the sediments deposited.

Manganese formation is further found only at stations 246 and 162. At St. 162 a fairly strong bottom current is evident, this station forms part of the sill between the Wetar and Sawoe basins.

Besides these there are strong bottom currents at St. 156 (hard bottom of marley limestone with film of manganese) upon the still between the Indian Ocean and the Timor trough, at St. 113 east of Sermata and at St. 70 in the Siboetoe strait where at St. 69 only pebbles were brought up.

The absence of a sediment at St. 196, as well as at St. 270, may be due to the sedimentary material sliding off, as the incline at this station is 17°.

It may be expected in general that strong currents will occur at all sills which form the connection between deep-sea basins, or between a basin and the open ocean. On map I hard bottom etc. however, are only marked where observations have been carried out.

6. REVIEW OF THE MECHANICAL ANALYSES OF THE SEDIMENTS,

The principle factors which determine the mechanical composition of the sediments, according to Pratje (125) are:

1. the material contributed to the sediment,
2. marine currents,
3. the bottom configuration, which in its turn effects the currents,
4. the composition of the sea-water, which effects the settling velocity of the particles and the solvent action for calcium carbonate,
5. animal and plant life.

For the sediments of the eastern part of the Neth. Ind. Archipelago must be added that:

a. in connection with aeolian distribution of volcanic material, the distance from a volcano and the direction of the wind during an eruption are factors which determine the mechanical composition of the sediments formed by this ash, as has been made plain above in the discussion of Volcanic Muds.

b. in various cases a connection can be observed between the grain-size of a sediment and the distance from the coast from which the material of the sediment is derived.

Revelle and Shepard (128) who, with Trask (160) consider that „the texture and other characteristics of sediments are more closely related to bottom configuration than to actual depth or distance from shore", acknowledge that „distance from shore does play some rôle".

Occasionally use could be made of the connection between the distance from shore and the grain diameter of the terrigenous detritus to make the derivation of the material of a sediment from a particular coast more admissible, as has been shown above in the treatment of Terrigenous Muds.

The sediments with which this research is occupied show in particular the great effect of the material contributed and of the currents, which often overwhelm or abolish the effect of the bottom configuration.

The effect of the fauna is only distinctly seen where the supply of material from the surrounding islands is small; the size of the Foraminifera and of other organisms which belong to the sand fractions, then determine to a great extent the mechanical composition of the sediments. In such areas the mechanical composition follows the bottom configuration, as there the foraminiferous, i.e. sandy sediments on sub-marine ridges and the fine-grained sediments in the adjacent troughs and basins are met with. This is partly due to the fact that the calcareous organisms are usually dissolved in the deeper layers of water (where the sill of the basin is not shallow) and on the other hand from the decline of current strength in the deeper layers, so that the finer material is carried by the currents over banks, ridges and submarine slopes and collects in the basins.

The fact that the mechanical composition of the sediments in the eastern Neth. Ind. Archipelago only for a small part follow the bottom configuration, does not prevent the finest settling particles collecting at the bottom of the larger basins. The nature of the transported material as well as the strong currents in the upper layers, however, often cause much silty and sandy material to be deposited in the large deep basins as well.

The mechanical composition of the sediments in the basins and troughs are here dealt with in succession.

In the *Celebes sea,* that is the largest basin of the Neth. Ind. Archipelago, the mechanical composition of the sediments is greatly effected by the eruption products of the volcanoes of the Sangih

Archipelago, which are distributed far into the Celebes sea by the strong currents. Consequently, independent of the bottom configuration, the clay content of the sediments increases from the Sangih Archipelago, which bounds the sea in the east, towards the W.N.W. In the neighbourhood of the coast of Borneo the clay content again declines somewhat, as the terrigenous material brought by the rivers of Borneo also contains sand. The two samples 44 and 51, raised from only 400 m depth close to the coast of Maratoea and North Celebes respectively, only corresponding to the bottom configuration are sands, namely a terrigenous sand and a coral sand. Generally speaking, however, the mechanical composition of the sediments in the Celebes sea, does not follow the bottom configuration. The sediments in the shallow *Soeloe Archipelago* however which bounds the Celebes sea to the N.W. consist of Coral Sand in accordance with the bottom configuration. Near this Archipelago sample 73 is a sediment consisting partly of sandy coral reef detritus and partly of Globigerina Sand. At the sill between the Soeloe sea and the Celebes sea as at the sills of the Sangih Archipelago „hard bottom" or „coarse deposits" occur.

In the *Soeloe sea* where the temperature of the water is higher than in the Celebes sea, while it is only slowly renewed, in contrast to the other basins of the Archipelago, Globigerina Ooze is found to a depth of 4500 m. It contains a considerable amount of clay, which increases with increasing distance from the Soeloe Archipelago. The effect of the compostion of the sea-water upon the mechanical composition of the sediments is here expressed in the sand content, the sand consisting chiefly of shells of Foraminifera.

In the *Sangih trough,* lying west of the Talaud islands medium to fine-grained terrigenous sediments are deposited. The Sangih trough is a comparatively small narrow trough, it cannot be expected that a selection according to grain-size would be exercised here.

In the *Mindanao trough* the mechanical composition of the sediments is determined by the nature of the contributed material and by the distance from the coast, while no connection with the bottom configuration can be detected. The sediments by South Mindanao are coarser than by North Mindanao (261, 262); the mean grain-size in 265 is larger than in 264, which lies in the deepest part of the trough, and that of 264 is larger than that of 263, which lies on the opposite side of the trough at a much smaller depth. In the southern part of the trough the sediments 260 and 271 which lie close together, are of medium and fine-grained composition respectively, possibly due to the precipitation or sliding of material. The presence of „hard bottom" on the steep slope of the trough (St. 270) forms another indication of this process.

In the *Morotai basin* sediment 284 lies in the deepest part and like the sediments in the Sangih trough, it is medium to fine-grained. The mechanical composition of the sediments is in accordance with the bottom configuration in so far, that the degree of fineness increases with the depth. Sediment 285 is fine sand with little clay, and lies at 2000 m depth. Sediments 283 and 286 deposited at 600 m depth are coarse sandy.

Sediments 290 and 299 (see photo 13) on the ridge of the Sangih Archipelago are also coarse sandy, like the sediments 293 and 269 deposited by the Talaud and Nanoesa islands at 850 and 550 m depth. In the straits between the islands of the Sangih Archipelago and at stations 294, 295 (see photo 1) and 267 strong currents cause a „hard bottom" or „coarse deposits".

In the northern part of the *Molukken sea* the mechanical composition of the sediments is chiefly determined by the composition of the volcanic ash distributed here by the Roeang and by the volcanoes of Halmaheira, while currents also have a local effect, as by the coasts of Halmaheira and of the Minahassa.

In the small *Ternate trough,* which lying in the west of the island of Ternate, forms a part of the Molukken sea, there are alternate layers of volcanic ash mixed with clay and hard layers of coarse volcanic ash, thus here too, the mechanical composition is chiefly determined by the nature of the volcanic material.

In the *southern Molukken sea,* the effect of the volcanic ash upon the mechanical composition of the sediments is less marked. The fineness of the sediment here increases with increasing distance from the shore following the series 339, 338, 337, 336, 335, 333, these samples being raised from 450, 1800, 3850, 2350, 2100 and 2700 m depth. A connection with the bottom configuration is thus perceptable in the sediments near the coast. Sediment 334 lying 60 km from the coast of Mangole

at 2700 m depth is very fine-grained, like 333, so that in the mechanical composition of these sediments, the nature of the supplied material is again an important factor.

In the deepest part of the *Batjan basin*, which lies in the S.E. part of the Molukken sea, sample 80 (4600 m) is of coarser grained composition than 227 (2950 m) which belongs to the S.W. side of the basin. This is to be attributed to the different derivation of the material of the two sediments. The mechanical composition again does not correspond to the bottom configuration, but is chiefly effected by the nature of the contributed material.

At St. 81, in the Lifamatola straits and south of Sanana sill currents take effect.

In the *Northern Banda basin* a connection between the mechanical composition of the sediments and the bottom configuration can be observed. The large deep centre of the basin is a collecting ground for fine-grained sediments; on the west side of the basin, at St. 213 (1150 m) there is a sandy Globigerina Ooze. However, on the west side at St. 214 (3000 m depth) there is a sediment of finer grain than in the deeper basin, which must be ascribed to the finer condition of the material which is contributed from the Celebes side. On the other hand at St. 210 by the coast of Boeroe, in the deepest part of the basin (4900 m) a fine sandy sediment is deposited; this is due to the strong currents near the coast of Boeroe, which cause the sandy material to be unable to settle near the coast; at St. 211 (2050 m) 5 km from the coast, only fine rounded gravel is deposited (see photo 4). At the south coast of Taliaboe also the effect of strong currents is felt, at St. 217 (1400 m) at 20 km from the coast only angular pebbles and sand are deposited. The grain diameter of the sediments diminishes from the coast of Taliaboe to St. 214 and from the S.W. coast of Boeroe to St. 209.

Around the island of Boeroe the composition of the sediments is effected by strong currents, as in the vicinity of the coasts only gravel and pebbles were brought up. The strongest currents seem to flow at St. 230 (1400 m) N.E. of Boeroe, as here at 20 km from the coast *rounded* pebbles were brought up. Considerably strong currents also run by the east coast at St. 256 (1250 m), the south coast at St. 252 (1500 m) and the S.E. coast at St. 211 (2050 m), where coarse and fine angular gravel (photo 2), rounded gravel (photo 3) and coarse and fine rounded gravel (photo 4) were found. The strong currents near the coast cause the sandy material, which would otherwise be deposited close to the coast, to be carried further away. They also account for there being similar fine sandy sediments formed at different places to the south of Boeroe and Ceram, namely at stations 253^{L}, 255, 251 and 210 which lie at 5, 20, 50 and 20 km from the shore. The strength of the currents near Boeroe can be appreciated if the sediments near the coast are compared to the observations of Pratje (125) who measured a mean rate of 18—39 cm/sec by the Borkum Reef light ship, while the sediment deposited was of 0,1—0,5 mm size.

The fine sandy sediment 255 lies in the *Manipa basin*; at St. 253, in the deepest part of the basin only „trace clay" was raised. It is not surprising, considering the effect of the strong currents by Boeroe, that the mechanical composition of the sediments in this basin do not correspond to the bottom configuration.

The mechanical composition of the sediments south of Boeroe and Ambon decreases regularly in grain-size with the distance from the coast, this applies to samples 252, 251, 250 and to 253^{L}, 231, 232, 233 and 234. No connection can be traced with the bottom configuration, as St. 251 (5100 m) lies in the deepest part of the *Ambalaoe basin*, while the finer sediment 250 lies upon a ridge at 1050 m depth. The western Ambalaoe basin is no more the collecting place of the finest material than the Manipa basin. South of Ambon lies St. 232 (4600 m) in the deepest part of the eastern Ambalaoe basin, the sample contains more clay than 251, but still it is coarser grained than 233 (1750 m), which lies upon a ridge, although 233 contains somewhat more Globigerina Sand than 232.

From the coast of Middle Ceram to the *Southern Banda basin* the grain-size first diminishes (St. 360, 359), but sediment 358 lying in the deepest part is coarser grained than 360, while at St. 357 a „hard bottom" was found. The reason for 358 being coarser grained is that here finer and coarser layers which have been alternately deposited were sampled together by Dr. Kuenen, according to his description in the sampled upper 45 cm four layers of fine and three of coarser material are found. The coarser material consists only for a small part of pumice and recent-volcanic ash, it is chiefly composed of material from crystalline schists. It therefore seems probable that at St. 357 there has been a sliding of material, the slope is 14°, 21° (see table 2), and that the coarser

material precipitated at St. 358, perhaps mixed with a certain amount of recent-volcanic material from the Banda Api, collects at intervals.

In the *Southern Banda basin* the mechanical composition of the rest of the sediments is effected in varying degree by the volcanic ash from the Seroea, from Téon, Nila, the Woerlali on Damar, the Gg. Api north of Wetar and the Batoe Tara. This varying effect is very clearly visible at Sts. 245 and 241. At St. 245 five cm of volcanic sand from the Gg. Api north of Wetar were found upon a sediment which is composed of ash from this volcano and of fine clay, thus terrigenous material. At St. 241 a clay-rich sediment lies upon a volcanic ash. Although in this basin little correlation can be seen between the bottom configuration and the mechanical composition of the sediments, the fine terrigenous material certainly collects in the large basin. The fine-grained composition of 205, 235 and 249 witness to this, as does the content of fine terrigenous material in the great part of the other samples.

In the *Weber deep* the mechanical composition of sample 365 is effected by Seroea ash; sediments 322, 365, 364a and 369 in fact all consist largely of fine-grained material. On the other hand the deepest sediment 362 (7350 m) is a medium-grained deposit, while 369 also contains fine sandy material.

How much the precipitation of material from submarine ridges contribute here could not be found out. At St. 321, at 6600 m depth, nothing was brought up.

In the *Gulf of Boni* the grain diameter of the sediments, this applies to 191—190—192—193, decreases from north towards the south, independently of the depth and the distance from the coast. Here the effect is seen of the large rivers which enter the northern part of the Gulf of Boni and of the nature of the material which they bring down. The material transported by the rivers is not of a constant composition, as may be seen in the difference of grain-size in the upper and lower layer of sediment 191. It must be supposed that the sandy material is washed down in large quantities by the floods, while in the dry season only a smaller amount of finer material reaches the sea.

At St. 189 the varying amount of material brought by the rivers of the southern arm of Celebes is demonstrated by an alternation of layers of Terrigenous Mud and Globigerina Ooze. Moreover the lime-content and the mechanical composition of the strata vary.

Sediments 188 and 200 correspond to their positions, by a coastal shelf and a submarine ridge, in being coarse sandy.

In the *Saleyer trough*, which has a very steep wall by Saleyer, the grain-size of the sediment diminishes with increasing distance from the island.

The mechanical composition of the sediments in the *Flores sea* is greatly effected by volcanic ash, like that of the sediments in the Celebes sea and the southern Banda basin. The ashes from the Tambora eruption of 1815, especially, are deposited in the Flores sea; locally material from the Sangean Api (St. 169 and 180) and from the volcano Rokatinda on Paloeweh (St. 197, 317a) are found. Moreover in some places marine currents cause the volcanic ash to be deposited mixed with only little clay (see p. 93 and further); while strong currents cause „coarse deposit" at stations 195 and 195^{L}. The fine terrigenous material collects where the effect of the currents is not much felt, that is, in the deep eastern part of the Flores sea (St. 197) and to the north and south of the deepest part of the western Flores sea (stations 178, 179, 166, 175, 181). In all these sediments, moreover, there is some recent-volcanic material. The fine sandy sediment 182 represents possibly material from a submarine slide.

By the Paternoster and Postiljon islands Coral Sand and Mud are deposited in shallow seas (St. 182^{L} and 165) or, owing to the action of stronger currents, only a „trace" of volcanic ash (St. 183, 184) or a „trace" of clay and sand (St. 176).

Near the sill between the Flores sea and the Bali sea (St. 174) a thin layer of volcanic ash has been deposited upon the Globigerina Ooze.

In the *Bali sea* only two samples were raised, both of which consist chiefly of volcanic ash from the Tambora, here again the mechanical composition is determined by the nature of the contributed material.

On the S.E. part of the *Soenda shelf* fine-grained sediments are found, which may be partly residual and partly composed of river mud. Here again, therefore, there is no correlation between the bottom configuration and the mechanical composition of the sediments. A correlation of this

kind, however, can be traced in the sediments which are formed along the edges of the shelves and which consist of coarse to fine sandy material (St. 29, 34, 185).

In the *Makassar Strait* the mechanical analyses show no connection with the bottom configuration. The mechanical composition is determined by the material brought by the rivers of Celebes and Borneo, while material seems also to be carried from north to south through the straits. In the north, where no large rivers enter the sea, a fine-grained sediment is deposited at St. 43. Sediments 41, 40 and 39, the material of which comes from large rivers in Celebes, whose estuaries are not sanded up, are medium-grained; while sediments 39 and 38, on the Borneo side, are fine-grained, the Mahakam river seems to carry little sand into the sea, as sample 37, raised from only 60 m depth close to the delta is a very fine sediment. Volcanic ash from the Oena Oena effects to some extent the mechanical composition of the sediments 39, 40 and 41.

In the bay of Mamoedjoe a coarse sand (photo 6) is deposited at 1 km from the coast at St. 35^L (20 m), which has undoubtedly been selected by the breakers from material brought back to the coast (see p. 179) in the same way as has been observed on the north coast of Java. This is the opposite effect to what takes place when a strong current runs parallel to the coast, as at the coast of Boeroe, when the sand is transported to the sea.

In the southern part of the Makassar Strait the mechanical composition of some of the sediments is effected by material precipitated from the coast of Celebes. At St. 33 it has caused layers of different mechanical composition to settle. At 27—30 cm we find coarse grain, the layer of 6—20 cm examined in the sediment consists of fine sand with a grain diameter corresponding to sample 35, which lies nearer to the coast of Celebes (see p. 179). This precipitated tuff material is covered at St. 33 by a medium to fine-grained sediment with a mechanical composition corresponding to the material in the most southerly part of the Makassar Strait.

The mechanical composition of the sediments in the *Sawoe basin,* at least those in the neighbourhood of the coast of Flores, are effected by recent-volcanic ash from the Flores volcanoes. The Terrigenous Muds deposited further from the coast are medium to fine-grained sediments. Generally speaking the sediments in the Sawoe sea are more fine-grained the more southerly they are deposited. But sediment 157, deposited 5 km from the coast of Timor at only 450 m depth is coarse sandy.

Sediments 376 and 377 in the *Wetar basin,* only 30 km from the coast are medium to fine-grained.

On the submarine ridge which connects Timor with Ceram, between Timor and Leti (St. 375) lies a medium-grained sediment and by the island of Babar a finer grained one (St. 114). Both samples were taken 20 km from the coast and the difference in mechanical composition is to be attributed to the difference in the contributed terrigenous material. Sediment 364, lying on the top of the flat part of the ridge, is a sandy Globigerina Ooze; the Globigerina Ooze 370 on the top part of a gentle slope of the ridge contains little clay; while the Globigerina Ooze 368 further down a gentle slope of the ridge towards the Weber deep, is a fine-grained sediment; here the division of grains thus corresponds to the bottom configuration, as Revelle and Shepard (128) conceived it, sandy material being found on the ridges and banks and fine-grained material on the lower parts of gentle slopes and in basins. On the other hand at St. 363 nearer to the Aroe islands on the flat part of the ridge a fine-grained sediment was encountered.

Between Leti and Romang at St. 374 layers of Globigerina Ooze have been deposited, in which a higher lime content (i.e. a higher Foraminifera content) is accompanied by a lower content of fine terrigenous components. The varying settling velocity of the terrigenous material, as well as the bottom configuration here effects the mechanical composition of the sediments.

Sediment 320 on the Banda inner arc is chiefly sandy while sediment 242 on the northern slope is principally fine-grained, corresponding to the bottom configuration.

In the S.E. part of the Neth. Ind. Archipelago there appears to be more correspondence between the bottom configuration and the mechanical composition of the sediments than in the other part, although there are exceptions. The S.E. part includes the Halmaheira basin, the Ceram trough, the Aroe basin and the Timor trough with the surrounding shelves and ridges.

In the deeper part of the *Halmaheira basin* at St. 353 a Globigerina Ooze is deposited containing much clay. On the ridges north of the basin Coral Sands are found at stations 351 and 352. On a ridge south of the basin, at St. 84, 85 and 86 Globigerina Sands are found (photo 9 and 10). At Stations 83 and 354 strong currents have their effect as here round pebbles and nothing were found respectively.

In the area sloping gradually towards the Pacific Ocean, lying to the east of N. Halmaheira the fine-grained sediments 276 and 350 have been deposited.

In the small *Kaoe Bay* where the sediments lie only 5—10 km from the coast, the mechanical composition, naturally, is not determined by the bottom configuration, but by the composition of the supplied terrigenous material.

In the *Boeroe basin* and the *Ceram sea* below 1000 m depth fine-grained sediments are usually deposited; samples 257 and 328 only contain somewhat more fine sand, which is probably due to the derivation of the material. An exception is formed by sediment 327, at 1450 m depth to the north of West Ceram, which consists chiefly of fine sand. This may be due to the supply of coarser material by the rivers entering the sea here, for at St. 326, 10 km from the coast, chiefly gravel and sand are deposited (see photo 5), while the fine sand of sample 327 which is formed at 40 km from the coast, shows much the same mineralogical composition as 326. The mean grain-size of the sediments declines here in the direction following 326—327—328—355.

The greater or less amount of sand in the sediments on the ridges and shelves of the southern Ceram sea is related to the occurrence of areas with slight sedimentation of terrigenous material. The sediments on the shelves near to the coast (St. 87), therefore, contain more clay than those which lie further from the coast.

Sediment 96 forms an exception, it consists of fine sand with much clay, it is formed of limestone detritus from the neighbouring coast, which thus determines the mechanical composition at this station.

In the southern part of the *Aroe basin* fine material collects, on the other hand at St. 104 a fine sandy sediment is deposited. As this fine sandy material has been deposited in the deepest part of the Aroe basin it probably represents a precipitation, the simple mineralogical composition, moreover, suggests a local place of origin (see p. 175—176). Sediments 102 and 103 in the vicinity of Great Kei are coarse sandy in accordance with the bottom configuration, while sediment 97 in the north western continuation of the Aroe basin, is fine-grained. Near to the Aroe islands at St. 99 on the S.W. slope of the basin, lies a Globigerina Ooze containing a good deal of clay; contrary to what would be expected in connection with the bottom configuration a „trace clay" was brought up at St. 98 (550 m), near the top of this slope.

South of the Aroe basin, sediments 105 and 106B in accordance with the bottom configuration are sandy Globigerina Oozes. The bottom layer 106A, however, is very fine-grained, so that here either the conditions of sedimentation are changed or 106A represents a precipitation or slide of terrigenous material.

Sediments 107 and 110, east of Jamdena, contain more fine sand than the deeper lying sediments 108 and 109, all these samples, however, contain a considerable amount of clay, so that the mechanical composition of the sediments is determined not only by the bottom configuration, but to a large extent by the nature of the contributed material. Sediment 112 which, like 109 comes from the channel which connects the Aroe basin with the Timor trough, is also fine-grained; the same applies to sediment 111 (550 m) formed to the south of this channel, of which the mechanical composition is determined by the material transported from Australia, and to sediment 117 (600 m), which also seems to come from Australia while containing more sand than 111.

In the *Timor trough* all sediments are fine-grained, except sediment 125; here the effect of the contributed material is evident again in this sediment derived from Timor, which is even more coarse sanded than sediments 119 and 126 lying nearer to the coast. On the southern side of this part of the Timor sea the sediments are fine sandy, in this area of slight sedimentation of terrigenous material there is a more obvious correlation between the bottom configuration and the mechanical composition of the sediments than on the Timor side of the trough.

In the strait which forms the connection between the Timor trough and the Indian ocean, in the Dao and Sawoe straits, strong currents have their effect (hard bottom, no sample, coarse deposit). On the sides of the Sawoe and Dao straits in the vicinity of the islands Soemba, Sawoe and Rotti, coarse Globigerina and Coral Sands are deposited, apparently the currents along these side parts are strong enough to carry away the fine material so that we find a relation to the bottom configuration.

On the slope which leads from the small islands of Sawoe and Rotti to the Indian ocean, fine-grained sediments have been deposited (St. 141, 131), in the vicinity of the larger island of Soemba

a medium-grained sediment has formed (St. 143), the sediments deposited more southerly in the Indian ocean are fine-grained (St. 144, 145, 146 and 382).

The above shows very clearly that in the areas of the Neth. Ind. Archipelago examined, the nature of the contributed material is the principle factor to determine the mechanical composition of the sediments. Moreover the marine currents exercise an influence which must not be underrated. Several examples could be given of the connection between the mechanical composition of the terrigenous sediments and the distance from the coast from which they are derived. The effect of the bottom configuration upon the grain diameter of the sediments is only expressed where the settling velocity of recent-volcanic and terrigenous material is low, i.e. on most of the submarine ridges and small shelves and in a part of the eastern and southern Neth. Ind. Archipelago. The effect of the flora and fauna is likewise confined to the areas of slight sedimentation.

CHAPTER V

RATE OF SETTLING OF THE SEDIMENTS

The calculation of the rate of settling of deep-sea sediments made by Schott (144, 145, 146) is founded upon the appearance of faunistic boundaries in these sediments. In a research on the sediments of the equatorial Atlantic ocean he observed that in most of the samples a layer bearing the pelagic Foraminifera, Globorotalia Menardii, covered a layer free from Globorotalia Menardii; in long samples this might be succeeded by another layer bearing Globorotalia Menardii. The thickness of the two upper layers usually varies between 10 and 40 cm. Near the coast both layers are thicker than in the middle of the ocean and in the south they are thicker than in the north. Where Globorotalia Menardii is absent the content of Globigerina bulloïdes and Globigerina inflata often rises. These two Globigerinidae are at present chiefly distributed in the temperate zone of the Atlantic Ocean. Schott draws the conclusion from the increasing occurrence of the Foraminifera Globigerina bulloïdes and Globigerina inflata which now live principally in cool water and from the disappearance of the now very widely spread and heat loving Globorotalia Menardii in the middle layer, that during the sedimentation of this layer the surface water of the Atlantic ocean was cooler. This decline of temperature of the equatorial Atlantic ocean in his opinion can only be accounted for by the ice age. Schott assumes that during the last ice age cold polar currents reached the equatorial part of the ocean and that the layer free from Globorotalia Menardii was deposited during the last ice period, while the renewed appearance of Globorotalia Menardii indicates an increase of temperature in the sea water, that is to say, the beginning of the post glacial period. The Globorotalia Menardii layer lying below the layer free from Globorotalia Menardii would then have been formed during the interglacial period.

Schott considers his explanation as a parallel to Philippi's interpretation of the alternating layers of Globigerina Ooze and Red Clay in the southern Indian Ocean (samples from the Valdivia-expedition).

Philippi (124) observed that the boundary between Globigerina Ooze and Red Clay on the sea-floor occurs at greater depth as the distance from the Antarctic increases, that is to say at greater depth according as the effect of the cold well-oxygenated water of the pole declines. The repeated alternation of Globigerina Ooze and Red Clay which was found in several samples is here also accounted for by the flow of the cold polar water, which extended farther north in the glacial period.

Schott moreover ascertained that the boundary between Globigerina Ooze and Red Clay in the equatorial Atlantic Ocean corresponded to a faunistic boundary. A similar faunistic boundary could also be found near the African coast in some sediments, where Blue Mud was covered by Globigerina Ooze.

In this particular case the boundary was again caused by change of climate, thus, when the surface water was colder a less calcareous bottom mud was deposited, while the occurrence of colder surface water is supposed to come with a glacial period.

Schott made use of these faunistic boundaries to calculate the rate of sedimentation of recent Globigerina Ooze, Blue Mud and Red Clay in the northern part of the equatorial Atlantic ocean. In doing so he set the last post-glacial period at 20.000 years.

The rate of deposit calculated thus varies for:

Globigerina Ooze	of	0,53—2,13	cm	per	1000 years
Blue Mud	„	0,9 —3,3	„	„	1000 years
Red Clay	„	$<$ 0,5 —1,33	„	„	1000 years

In an analogous way Schott calculates from the observations of Philippi (German South Pole

Expedition 1901—1903) the settling velocity of a number of samples from the southern Indian Ocean, in which Globigerina Ooze lies upon Red Clay. He arrives at a settling velocity for the Globigerina Ooze which is about half of that for Globigerina Ooze in the equatorial Atlantic Ocean. (No observations concerning the presence of Globorotalia Menardii in these Globigerina Oozes were made). The sparse samples seem to indicate that the settling velocity of Globigerina Ooze here increases in the direction of the equator; in the transition area between Globigerina Ooze and Diatom Ooze the thickness of the post-glacial layer of Globigerina Ooze was 5—8 cm, north of 40° S. latitude this layer was as much as 15—20 cm thick.

Twenhofel (162) calculated a settling velocity for the anorganic components of deep-sea deposits far from the coast of 0,35 cm per 1000 years. This calculation, which is founded upon unverifiable assumptions, yields the same order of magnitude as determined by Schott for Red Clay.

The question now arises of whether in the eastern Netherlands Indian Archipelago the glacial period has exercised a similar influence, that is to say, whether an increasing effect of cold Polar water can be demonstrated by the occurrence of Globorotalia Menardii-free strata in long samples.

The thickness of the Globigerina Ooze layer deposited after the last glacial period should perhaps be considered locally somewhat greater in the East Ind. Archipelago than in the equatorial Atlantic ocean, because of the greater admixture of terrigenous material in this area, lying as it does near to many coasts. The thickness of the layer, considering the content of carbonate-free terrigenous material in the long samples of Globigerina Ooze, may be taken at double that in the equatorial Atlantic ocean (which is probably too high), thus at 20—80 cm thickness. A correction must then be applied for the fact that a considerable part of the sediments in the East Ind. Archipelago contains limestone and coral-rock detritus; the carbonate content of the sediments is then only partially due to organisms belonging to the Globigerina Ooze. The mean foraminifera content in the fractions above 20 μ in 15 typical Globigerina Oozes, which contain no coral-rock or limestone detritus, amounts to 87% of the total calcium carbonate content. In the four long samples of Globigerina Ooze which we have at our disposal the content of foraminifera larger than 20 μ is 83% (mean of 6 samples 374 A-H), 70% (mean of 3 samples 193, 193A en 193E), 26% (mean of 2 samples 382C and 382B) and 46% (mean of 7 samples 189 A-C and 189 I-V) of the total calcium carbonate content. In sediment 374, which has the highest foraminifera percentage, no limestone detritus was found. In sediment 193 aggregated calcite and calcite were found in fractions 5 and 6, in the finer material thus, which accords with the fact that these sediments contain material transported through the Gulf of Boni, where all sediments contain limestone detritus. By a comparison of the content of calcite + undefined calcareous debris of samples 189 in table 25 with the foraminifera percentage of these sediments, which are for 189 I 52%, 189 III 80%, 189 IV 24%, 189 V 52%, 189 A 24%, 189 B 37% and 189 C 51%, the connection between these percentages and the content of limestone detritus becomes very clear. Sediment 382 also contains carbonate transported from elsewhere. If a correction be further applied for this content of limestone and coral-rock detritus, that is taking into account the foraminifera percentages above 20 μ, the length of the sediment that has been deposited at these stations since the glacial period amounts to $\frac{87}{83}, \frac{87}{70}, \frac{87}{46}$, and $\frac{87}{26} \times$ 20—80 cm respectively, that is 21—84 cm for 374, 25—100 cm for 193, 38—151 cm for 189 and 67—268 cm for 382. Sediments 374, 193 and 189 which are 206, 174 and 168 cm long respectively, are sufficient to show the presence of a faunistic boundary; for sediment 382, which is 178 cm long, it is uncertain.

The post glacial period in the southern hemisphere, according to Köppen and Wegener (93) has already lasted for 30.000 years, 1,5 times thus as long as in the northern hemisphere; according to others it is the same as in the northern hemisphere, while Schott, considering that there is a deposit of only 15—20 cm Globigerina Ooze upon Red Clay in the Indian ocean north of 40° S. lat., estimates the time as shorter. For the southern part of the Archipelago thus it is not necessary to assume that the post glacial layer was thicker than stated above.

From sediments 382 and 189 which are 178 and 168 cm long, 20 layers about 1 cm thick at constant distance from one another were taken and washed in a ½ mm sieve. The residue upon the sieve always contained Globorotalia Menardii.

The short sample 189 I-V, in the same way, contained Globorotalia Menardii in all the layers

of 0—35 cm which were submitted to examination, the same applies to the layers 189A, 189B and 189C and to 382B and 382C of the long samples.

In these two sediments 189 and 382, therefore, the alternating layers of Globigerina Ooze and Terrigenous Mud are not accompanied by a faunistic boundary.

Sediments 374 and 193, 206 and 174 cm long respectively, consist entirely of Globigerina Ooze, 374 has varying lime-content, 193 is a very homogeneous Globigerina Ooze with a constant lime and Foraminifera content in the successive layers. The strata examined in these samples always contained Globorotalia Menardii.

The other long samples are the Terrigenous Muds 330, 331 and 364a, which were no use for determining the species of Foraminifera, as they contained practically nothing but fragments Neither is the long sample of Volcanic Mud suited to this purpose as the absence of Globorotalia Menardii in rapidly deposited layers of ash cannot be regarded as a faunistic boundary. The three layers of 347 which were examined contained Globorotalia Menardii.

At St. 106 a Terrigenous Mud poor in carbonate is covered by a typical Globigerina Ooze. Both samples contain Globorotalia Menardii, so that here again there is no faunistic boundary.

It may thus be concluded from this research for strata free from Globorotalia Menardii that *no indication can be found of a change in climate during the last glacial period in that part of the Indian Ocean which surrounds the eastern Indian Archipelago.*

It is therefore all the more remarkable that in the northern part of the eastern Neth. Ind. Archipelago cold currents from the Pacific ocean still make their effect felt in recent times, as observed by the eastern sills and in the deep centre of the Celebes sea. It is not here a case of cold surface currents; no more than it is in Philippi's explanation of the presence of Red Clay below the Globigerina Ooze in the Indian ocean, but must be due to cold depth currents. In the Indian basins, however, the bottom currents do not come directly from the pole, but the water comes from medium depths.

The presence of Globorotalia Menardii in the rest of the deep-sea sediments is treated in Chapter VII.

The settling velocity of Volcanic Muds and Terrigenous Muds in the eastern Netherlands Indian Archipelago will naturally show a greater variety than that of the terrigenous deposits or „Blue Mud" in the open oceans. The effect produced upon the settling velocity of the Terrigenous Muds by the vicinity of larger islands is demonstrated by the low relative carbonate content of these sediments. The Terrigenous Muds have a high rate of settling in the Strait of Makassar lying between two large islands, in the Flores sea, in the western Ceram sea and in the Kao bay of Halmaheira; in the northern Banda sea it is somewhat less rapid, as in the Sawoe sea, round about Timor and in the Celebes sea along the coasts of Borneo and North Celebes. At St. 358 and 360 between Banda and Ceram the rate of sedimentation of the Terrigenous Mud seems to be fairly high, as notwithstanding the frequency of the eruptions of the Banda Api the terrigenous material greatly outweighs the volcanic material in these deposits. The settling velocity of Volcanic Mud is high in the vicinity of volcanoes which have been very active in recent times, like the Tambora, the Batoe Tara, the Gg. Api North of Wetar, the Seroea, the Gg. Api Siaoe, the Banoea Woehoe etc. (see also p. 95).

The deposition of terrigenous components is small in the most eastern part of the Java sea, in the vicinity of shelves (Sahoel shelf, Soenda shelf, Spermonde shelf) and upon submarine ridges, like the Ceram-Timor outer arc from Mid-Ceram to west of Babar, upon the ridges and shallows between the Vogelkop of New Guinea and Misool on the one hand and Halmaheira with Obi Major on the other, between Mindanao and Sangihe, upon and in the vicinity of the Soeloe Archipelago, by the Paternoster and Postiljon islands, between South Celebes and the Tijger islands, south of Kabaena and Moeton, by the Toekang besi islands etc. Moreover by smaller islands like Soemba and east of Morotai and the Talaud and Nanoesa islands in the Pacific ocean. More or less strong bottom currents may diminish the rate of settling or even reduce it to zero.

The sediments at stations 183 and 184 form a good illustration of the combined effect of a small supply of material and marine currents; they lie to the north of the coral reefs and atols of the Paternoster and Postiljon islands. For the formation of coral reefs it is essential that there should be practically no mud in the sea-water and that the water should be in lively motion. The currents at stations 183 and 184 cannot be compared to the strong marine currents, otherwise the volcanic ash which is chiefly from 100—10 μ and mostly consists of volcanic glass, would not be able to subside.

But the currents appear to be strong enough to prevent the sinking of clay particles. It must here not be forgotten that the rate of settling is dependant not only upon the diameter and form of the particles, their specific gravity and the strength of current, but also upon the concentration of the clay particles in the sea-water. Increasing concentration of clay particles increases their coagulation, thus raising the rate of settling. A low clay content in the sea-water and a considerable strength of current are factors which strengthen each other and delay or prevent the deposition of clay particles.

The fact that the date of the great Tambora eruption is known (1815), while in some of the sediments containing Tambora ash the lower limit of the ash could be observed, makes it possible to determine the rate of settling of the fine Terrigenous Mud which was deposited with the ash. Sediments 173, 175, 179 and 180 could be used for this determination.

Sample 180 is particularly suitable for this purpose, as there is a layer of coarser ash at the bottom of the sediment, which must have been supplied during the most violent outburst of the Tambora and rapidly deposited, thus showing the lower limit of the Tambora ash. Sample 180 consists for about 60% of volcanic ash, it contains 5,2% calcium carbonate and some 5% siliceous organisms. The content of terrigenous clay particles is about 25 to 30%, that is to say that the terrigenous admixture represents a layer of about 11 cm.

In sample 179 the volcanic ash is found in the upper 10 cm. From the mineralogical composition of the top layer of 35 cm. it was calculated that the ash layer would be 3 cm thick. The layer of terrigenous clay deposited at the same time may be fixed at about 6 cm.

In sediment 175 volcanic ash is met with over the whole depth of 25 cm, the ash content above being, however, slightly lower than below. Considering the composition of the sand fractions examined, the form of the ash diagrams (167, 173) in this region and the mechanical composition of sample 175 the content of volcanic ash may be calculated at about 12%. The calcium carbonate content of sample 175 is 22.7% and the content of siliceous organisms $\pm$ 3%. The content of terrigenous components, therefore, represents some 60% of the sample. The layer of Terrigenous Mud which was deposited simultaneously with the Tambora ash, therefore, at St. 175 amounts to at least 15 cm as it is not certain that in deeper layers which have not been sampled there is no Tambora ash.

Sample 173 of 15 cm length consists for 80% of volcanic ash, it contains 7,1% calcium carbonate and about 0,4% siliceous organisms. In this case the terrigenous components which were deposited at the same time as the Tambora ash represent a layer of at most 2 cm thickness.

The rate of settling of the Terrigenous Mud at these stations in the Bali sea and the Flores sea varies, thus, between 2 and at least 15 cm per 115 years, that is a mean of 75 cm per 1000 years. These values for the rate of sedimentation of Terrigenous Mud or Blue Mud are on an average some 50 times as high as what Schott calculated for the Blue Mud in the equatorial Atlantic ocean. It is certainly to be expected that the rate of settling of Blue Mud in the basins of the Neth. Ind. Archipelago should be higher and vary more conspicuously than in the open oceans far from land.

In one case a layer of Tambora ash 3 cm thick lies upon Globigerina Ooze, namely at St. 174; while on the Tambora ash again a layer not more than 1 mm thick of Globigerina Ooze has formed. The settling velocity of the Globigerina Ooze is here, therefore, about 1 cm per 1000 years, that is to say it is of the order of magnitude that Schott gives for the Globigerina Ooze of the equatorial Atlantic ocean.

Moreover only a small deposition of terrigenous material appears to have taken place at St. 174 during the 115 years that have elapsed between the eruption of the Tambora and the sampling by the Snellius expedition. The settling velocity of Terrigenous Mud is here more of the order of magnitude given by Schott. Probably this is connected with the fact that St. 174 lies in the area where fairly strong currents run from east to west in the upper layers of the sea-water and moreover in the vicinity of the sill which forms the connection between the Bali and Flores seas.

The composition of sediment 41 offers yet another opportunity for estimating the settling velocity of Terrigenous Mud. In this 38 cm sample (table 2) at 2—3 cm and at 10—11 cm depth layers containing much mica and of a different colour are found. The upper layer is most probably derived from the eruption of the Oena Oena in 1899. During the full 30 years till the sampling by the Snellius expedition a layer 2 cm thick has formed above this. The settling velocity of the Terrigenous Mud at St. 41 must, therefore, be about 6 cm per 100 years or 60 cm per 1000 years; thus it is of the same order of magnitude as that of the Terrigenous Muds of the Flores sea.

The settling velocity of Globigerina Ooze should further be estimated by calculating how much Globigerina Ooze is deposited in the sediment with the ash of the Oena Oena or the Tambora since the latest eruption. For this purpose, however, only sample 41 which bears Oena Oena ash would come into consideration, as samples 173, 175, 179 and 180 which bear Tambora ash contain coral rock and limestone detritus, so that it cannot be ascertained what part of the lime in these samples should be attributed to the Globigerina Ooze; it is all the more difficult because with the coral lime recent organisms are transported from the coral reefs and banks.

Sediment 41 contains 3,6% lime. Assuming that the lime is distributed evenly throughout the sediment, in 30 years 0,072 cm Globigerina Ooze would be deposited with the layer of 2 cm Terrigenous Mud. The rate of settling of the Globigerina Ooze at St. 41 would then be 2,4 cm per 1000 years. This rate of settling for the Globigerina Ooze, which may thus be regarded independently of the terrigenous material, is scarcely higher than what Schott gives for the rate of sedimentation of the Globigerina Ooze in the equatorial Atlantic Ocean. For the present, therefore, there is no reason for assuming that the rate of sedimentation of the Globigerina Oozes in the East Indian Archipelago and in the tropical part of the Atlantic Ocean are at great variance with one another. It is moreover difficult to suppose that with the same temperature of the surface water the production of Foraminifera in these two areas would differ very greatly.

So that while it may be said of the region marked on map I as Globigerina Ooze that the layer deposited since the last glacial period will vary from 20 to 100 cm in thickness, the rate of settling of the Terrigenous Muds will show a much greater variation than in the equatorial Atlantic Ocean. In the Flores and Bali seas and in the Makassar Strait settling velocities were calculated which on an average correspond to a deposit of 15 m since the latest glacial period.

On the other hand the thickness of the layer of Terrigenous Mud since then deposited upon the eastern Soenda shelf, considering the admissible presence of a relict bottom belonging to the old Soenda shelf in the 43 cm thick sample 26 (and the low content of terrigenous material in the Globigerina Ooze 29), amounts to less than 40 cm. Moreover the comparatively high content of glauconite in both samples indicates a low settling velocity of terrigenous material. As was shown in chap. IV the Aroe islands are surrounded by a region of small sedimentation which seems to extend into the Southern Aroe basin. Further the rate of settling of terrigenous material is comparatively low in a large part of the Soeloe basin, otherwise no Globigerina Ooze would have been able to form here. In the region of the smaller islands the rate of deposition of the terrigenous material may also be fairly low, this is confirmed by the relatively high lime content at stations 205, 373, 369, 353 etc.

The application of Dr. Kuenen's conclusion that the postpleistocene sedimentation of the Moluccan basins has in general exceeded 2 m , in my opinion, should be limited to the deepest part of the basins and troughs, while the Soeloe basin should be excepted from it.

CHAPTER VI

RÖNTGENOGRAPHIC EXAMINATION

with the collaboration of Dr. J. Ch. L. Favejee

The röntgenographic examination was undertaken in the first place to ascertain whether the composition of the clay fractions of the Volcanic Muds could be compared with that of the clay fractions of the Terrigenous Muds. The mineral content of the Volcanic Muds varies very greatly, while so far very little attention has been paid to the composition of the clay fractions of these sediments, which often form the greater part of the samples. In the second place it was important to compare the composition of the clay fractions of the same sample with one another and to trace in how far the composition of the clay casts in that sample corresponded to the clay fractions.

As only a limited number of röntgenographic photo could be made three samples were selected for the research where the minerals were of recent-volcanic origin and further two Terrigenous Muds and one Globigerina Ooze.

The röntgenographic examination of these 6 samples was carried out by Dr. J. Ch. L. Favejee by the method he describes (bibl. 54 and 55). The results of the examination are given in table 27.

TABLE 27

No.	Fr.	quartz	muscovite	montmo-rillonite	kaolinite	calcite	cristo-balite	felspar
167	2 —5 μ	scarce	scarce	fair	scarce	little	trace?	little
	0,5—2 μ	scarce	scarce	fair	little	fair	trace?	scarce
	<0,5 μ	trace		fair	little		little	
194B	0,5—1 mm	little	little	fair	little	moderate		trace
	2 —5 μ	moderate		dominant	little	moderate		trace
	<0,5 μ	trace		abundant	little	moderate	scarce	
241A	0,5— 1 mm	moderate	fair	fair	moderate			trace
	2 —5 μ	moderate	abundant	fair	moderate	trace		trace
	0,5—2 μ	little	fair	fair	moderate	scarce		trace
	<0,5 μ	scarce	moderate	dominant	moderate	scarce		
330A	0,5—1 mm	little	fair	fair	little	little		
	2 —5μ	moderate	abundant	fair	moderate	scarce		trace
	<0,5 μ	scarce	moderate	fair	little	little	trace	
111	0,5—1 mm	little	moderate	moderate	scarce	fair		
	<0,5 μ	trace	moderate	fair	little	moderate		
107	0,5—1 mm	little	moderate	moderate	scarce	fair		
	<0,5 μ	trace	moderate	dominant	little	fair		

In this table the amount of a particular mineral found (by determination of the intensity of the

interference lines on the Debye-Scherrer diagram) is indicated by the series: trace-scarce-little-moderate-fair-abundant-dominant. The expression „trace" in this table has a different meaning to when used in the mineralogical tables; it means here that the content of the clay mineral in question is less than 2%.

If the clay fractions in each sample are compared with one another, the quartz, muscovite and felspar contents prove to decline with an increasing degree of fineness of the clay fraction; felspar is not to be detected at all in the finest fraction. The kaolinite content remains about the same in all clay fractions. The montmorillonite content increases with the fineness of the fraction, while cristobalite, if it is present, is chiefly detected in the finest fraction, which contains the particles smaller than 0,5 μ. The occurrence of α-cristobalite was first demonstrated by Hardon and Favejee (65) in soils in Java, especially in „white earth derived from dacitic tuff" in the residency of Bantam.

The composition of the clay casts in fraction 0,5—1 mm corresponds best to the composition of the clay fraction 0,5—2 μ as is shown in sample 241A; in samples 194B and 330A this fraction was not examined, but the composition of the clay casts in these samples lies between that of fractions 2—5 μ and <0,5 μ. The clay casts always prove to contain the same minerals, also in samples 111 and 107, as the clay fractions of the sample in question. These clay casts, which follow the form of the cavities of the Foraminifera and are partly still found within the Foraminifera, therefore, in accordance with the hypothesis of von Gümbel (63), are probably formed gradually by clay deposits in the dead Foraminifera which have sunk to the bottom.

In all the samples all the clay fractions together contain a considerable amount of montmorillonite and a small to moderate amount of kaolinite. The composition of the fractions smaller than 5 μ differs in these samples chiefly through the variety of quartz and muscovite content and by the presence or absence of felspar and cristobalite.

Let us now compare the sand and clay fractions of these 6 samples.

The minerals in the sand fractions larger than 20 μ of samples 167 and 194B consist entirely of recent-volcanic material, in 167 it is derived from the Tambora, in 194B from the Batoe Tara. The sand fractions of sample 241A consist almost entirely of recent-volcanic material, although traces of epidote were found and in fraction 50—20 μ a little muscovite, indicating a very small contribution of terrigenous material. The minerals in samples 330A, 111 and 107 are composed of terrigenous detritus (see chap. IV). The sand fractions of sample 330A contain much plagioclase, quartz and muscovite; the sand fractions of 111 and 107 contain relatively much plagioclase and quartz with less muscovite.

The content of quartz and muscovite of the sand fractions and clay fractions of the Terrigenous Muds 330A, 111 and of the Globigerina Ooze 107 correspond to one another, while on the contrary, the content of quartz and muscovite of the sand fractions and the clay fractions of the so called Volcanic Muds form a sharp contrast. From this it may be seen that the last samples (167, 194B and 241A) contain terrigenous detritus in the clay fractions, as quartz and muscovite cannot be regarded as secondary formations and are no part of the recent-volcanic material of these samples.

It is the most probable that the montmorillonite and the kaolinite in the clay fractions of samples 167, 194B and 241A form terrigenous detritus also, as the volcanic ash of these samples is very fresh, it shows no decomposition phenomena, so that the formation of clay minerals in the sea from this ash is improbable. It is impossible to say in how far a part of the clay minerals may be regarded as material carried away with the ash of the eruption.

The α-cristobalite in these sediments is probably a secondary formation. The only soils in which this mineral has so far been detected may be regarded as bog formations.

The clay fractions of these 6 samples, taken from the Ceram sea, the Banda sea and the Arafoera sea have a good deal of qualitative resemblance to one another. The components of the clay fractions prove to consist largely of terrigenous detritus, not counting the lime-content and the small amount of felspar and cristobalite. The presence of the fractions below 5 μ in the sediment, therefore, indicates the presence of terrigenous detritus, independent of the composition of the sand fractions of the deep-sea sediments. It follows that in judging of the composition of the deep-sea sediments and especially in the classification of the Volcanic Muds the mechanical composition of the sediments may not be left out of account, as if only the composition of the sand fractions

is considered and not the clay percentage of the samples, an incorrect impression, or none at all, is given of the content of terrigenous material.

A comparison of the mineralogical composition of the sand and clay fractions of the above samples in connection with the mechanical composition brings this out very clearly.

The mechanical composition of sediment 167 (see chapter IV, fig. 1) shows an ash curve with a peak in fraction 50—20 μ; the sample, considering the mineralogical composition of the sand fractions, consists of Tambora ash with which only 18% of clay is mixed. The relatively low content of quartz and muscovite in the clay fractions (table 27) indicates that terrigenous detritus although present in the sample probably forms less than 10% of it.

The mechanical composition of sample 194B (fig. 6) shows three peaks, in the fraction 500—200 μ, caused by a relatively high content of Foraminifera particles and clay casts of this size, in fraction 50—20 μ caused by the Batoe Tara ash curve having a maximum in this fraction, and in fraction 5—2 μ, which is to be attributed to a high content of quartz and clay minerals of these measurements, that is, to terrigenous detritus of that size. This top frequently occurs in the clay fractions, it is partly due to a high content of terrigenous detritus, such as quartz and muscovite and may be partly caused by an insufficient peptisation of the clay minerals in the mechanical analysis. The clay content of sample 194B is some 50%, the quartz content of the clay fractions is higher than in 167, thus the presence of terrigenous material in sample 194B is very pronounced. The presence of a high percentage of clay fractions is here accompanied by a strong terrigenous admixture, although the sand fractions which contain very beautiful tephritic material of which only the leucite is perhaps affected, give no indication of it.

A still larger amount of terrigenous material is contained in sample 241A. The mechanical diagrams of 241A and of the Terrigenous Mud 330A (fig. 8 and 16) only have peaks in fraction 2—5 μ. The clay fractions of 241A contain considerable amounts of muscovite, while in the sand fractions only a very small quantity of this mineral is found; the presence of quartz was also clearly perceived in the clay fractions. The composition of these clay fractions is practically the same as in the Terrigenous Mud 330A, which contains no volcanic material at all. Although the sand fractions of sample 241A consist practically entirely of recent-volcanic material, terrigenous material appears to preponderate in the total sample.

The results of the röntgenographic examination of the fine fractions combined with the mineralogical examination of the sand fractions show that samples which formerly, on grounds of the examination of sand fractions only, were considered to be Volcanic Muds, must be classified to a great extent as mixed deposits. These sediments are indicated as „Terrigenous + Volcanic Muds".

The fact that has been demonstrated, that the finest fractions always contain terrigenous material and the observation that the particles of recent-volcanic ash are seldom smaller than 5 μ enables us to conclude from the results of the mechanical analyses and from the examination of the sand fractions whether a sediment belongs to the Volcanic Muds or to the Terrigenous + Volcanic Muds. In making the decision the lime content of the sample must be taken into consideration.

The composition of the clay fractions of the Terrigenous Mud 111 and the Globigerina Ooze 107 in the Arafoera sea again show a great quantitative resemblance to eachother.

By these arguments the conclusion of Correns (37), that the composition of the clay fractions of Red Clay, Blue Mud and Globigerina Ooze show no essential differences within certain areas, may be extended to the composition of the clay fractions of Volcanic Muds and is confirmed for the Terrigenous Muds and Globigerina Oozes.

CHAPTER VII

CALCAREOUS AND SILICEOUS ORGANISMS

The most important calcareous organisms are:

The Foraminifera.

Foraminifera are encountered in almost all the samples examined, as may be seen from the tables.

They are entirely absent from Volcanic Mud 52, the fine Volcanic Sand 245A (i.e. a layer of 5—10 cm at St. 245) and in sediment 365 close to the volcano Seroea. The absence of Foraminifera in these sediments, or layers of sediment, can be accounted for by a temporary large settling velocity of volcanic ash and sand connected with volcanic activity.

Foraminifera are distinguished as pelagic or benthonic. Pelagic Foraminifera form by far the greatest part of deep-sea sediments, they live as plankton principally in the layer of 0—200 m depth. When they die they sink to the bottom, and during that process they may be transported by currents. The calcareous shells may be partially or entirely dissolved during the process of sinking or if they lie uncovered for a long time on the sea floor, as we have discussed in an earlier chapter. Benthonic Foraminifera live on the sea floor, principally in the region of 0—200 m below the surface of the sea.

As the present author is not an expert on Foraminifera, the subject will only be treated briefly.

In examining the Foraminifera use has been made of bibl. 10, 39, 40, 41. The names of the Foraminifera are given according to Cushman's classification.

Cushman records 26 species of Foraminifera as pelagic, a small number of *species* therefore, compared to the thousands of benthonic living Foraminifera now known.

Of the pelagic Foraminifera there were found in the sediments from the Snellius-expedition chiefly: Globorotalia menardii, Globorotalia tumida, Globigerinoides sacculifera, Globigerinoides conglobata, Globigerinoides rubra, Globigerina bulloides, Globigerinella aequilateralis, Orbulina universa, Sphaeroidinella dehiscens, Pulleniatina obliquiloculata. At a few statoins moreover Globigerina dubia, Globigerina cretacea, Globigerinella digitata, Globigerina inflata, Hastigerina pelagica and Candeina nitida were found.

Globorotalia Mendardii was found in all the Globigerina Oozes except at St. 250. In this sediment the Foraminifera shells are practically all broken, so that it is uncertain whether Globorotalia Menardii may not have been contained in it.

In a great number of Volcanic and Terrigenous Muds also practically only fragments of Foraminifera are found and it is then impossible to determine the species. This is the case at stations, 261, 262, 264, 265, 260, 271, 275, 296, 291, 343, 337, 303, 75, 48, 47, 41, 40, 167, 197, 194, <u>202</u>, <u>245B</u>, <u>246A</u>, 241, 373, 235, 234, 251, 215, 218, 331, 212, 209, <u>208</u>, <u>322</u>, 362, <u>363</u>, <u>364A</u>, <u>80</u>, <u>227</u>, 229, 330, 257, <u>355</u>, <u>89</u>, <u>324</u>, <u>95</u>, <u>97</u>, <u>100</u>, <u>101</u>, <u>111</u>, <u>125</u>, 145, <u>146</u>, <u>153</u>, 161. At the 20 underlined stations, however, Globorotalia Menardii could be recognised.

Globorotalia Menardii is absent further only in the middle of the Celebes sea (St. 77, 53, 56, 301, 309), where the sediments have a small Foraminifera content, and with the exception of sample 77, moreover a very low lime content. As might be expected, some of the Coral Muds (St. 60, 51) and Terrigenous Muds (St. 25, 35^L, 37) lying above the 100 m line contain no Globorotalia Menardii.

Globorotalia Menardii thus proves to be generally distributed in the deep-sea sediments of the

easterly Netherlands Ind. Archipelago, which contain a sufficient number of complete Foraminifera. The content of Globorotalia Menardii in the sediments varies, without rising to any extreme heights. The highest content, namely 15—20% of the total lime content, occurs in the Globigerina Oozes 136, 133, 137, 138 and 269.

Globorotalia Tumida is always found in small quantities, it is present in 80% of the samples, which contain Globorotalia Menardii.

Globigerina sacculifera is the most usual Globigerinidae. Generally speaking it is the principal component of the pelagic Foraminifera in those areas where the water has little lime solvent action. In varying quantities *Globigerinoides conglobata, Globigerinoides rubra, Globigerina bulloides, Globigerinella aequilateralis, Pulleniatina obliquiloculata, Sphaeroidinella dehiscens* and *Orbulina universa* are found as well.

The wide distribution of Pulleniatina obliquiloculata and Sphaeroidinella dehiscens is remarkable, which with Globigerinoides conglobata occur down to greater depths than Globigerinoides rubra, Globigerinella aequilateralis and Orbulina universa; that is to say that the shells of the first mentioned Foraminifera dissolve less rapidly than those of the last.

The highest relative content of Pulleniatina obliquiloculata however is found in sediment 269, which was raised from 550 m depth.

In his report on „The Foraminifera of Globigerina Ooze" from the first great deep-sea expedition, the Challenger-expedition, Brady (10) explains that „under all circumstances the bulk of a Globigerina Ooze is made up of the shells of the pelagic species of Globigerina, Pulvinulina, Sphaeroidina and Pullenia; there are, however, invariably present a large number of nonpelagic forms, some of which are so frequently met with that they may be regarded as normal constituents of the deposit". Brady mentions 24 benthonic species which he found most frequently in 16 samples examined.

Brady's experience applies not only to Globigerina Ooze but to all deep-sea sediments.

Of the *benthonic Foraminifera* which Brady frequently found in the Globigerina Ooze of the oceans the following species constantly occur in the deep-sea sediments of the easterly Netherlands Indian Archipelago collected by the Snellius-expedition:

Verneuilina bradyi, Gaudryina scabra, Pyrgo depressa, Lagena marginata, Uvigerina pigmea, Uvigerina asperula, Virgulina schreibersiana, Gyroidina soldanii, Epistomina elegans, Sphaeroidina bulloides, Planulina wuellerstorfi, Cibicides pseudo ungeriana, Laticarinina pauperata.

Moreover Robulus orbicularis, Textularia quadrilatera, Syphonodosaria abyssorum, Bolivina hantkeniana and Bolivina robusta are frequently met with.

The most widely distributed are Planulina wuellerstorfi and Cibicides pseudo ungeriana, but they always occur in small quantities; Cibicides pseudo ungeriana was found in the shallow seas (0—200 m) but Planulina wuellerstorfi was not.

Of the other benthonic Foraminifera:

Miliolidae are fairly widely distributed, besides Pyrgo depressa and other species of the genus Pyrgo, it is chiefly the genera Quinqueloculina, Triloculina, Sigmoilina and Spiroloculina that are found.

Ophtalmidiidae are represented by the genera Cornuspira and Ophtalmidium.

Lagenidae are fairly widely distributed in the deep-sea sediments. The appearance of Lagenidae however is chiefly confined to the vicinity of shelves and islands of the East Indian Archipelago. The sediments in which they occur seldom lie more than 60 km from the shelves or islands. Besides Lagena marginata and Robulus orbicularis it is chiefly other species of the genera Lagena and Robulus (a.o. Robulus cultratus), the genera Frondicularia and Nodosaria (a.o. Nodosaria soluta) and the species Dentalina communis that are met with.

Polymorphinidae are seldom met with.

Nonionidae were also seldom found; Nonion umbilicatulum does occur but is sparsely distributed.

Buliminidae are widely distributed; they are found in some 75% of the samples examined. They are found especially in the size of 50—500 μ and sometimes occur in a great variety of species. The most common genera are Bolivina, Bulimina, Virgulina and Uvigerina of which the species Bolivina hantkeniana, Bolivina robusta, Virgulina schreibersiana, Uvigerina pigmea and Uvigerina asperula were repeatedly found.

Rotalidae, like the Buliminidae are widely distributed, they are also frequently found of the size of 50—500 μ. Besides Gyroidina soldanii and Epistomina elegans it is chiefly the genera Rotalia, Gyroidina and Discorbis which occur.

Cassidulinidae are not very frequent in the deep-sea samples, those most found were Cassidulina subglobosa and Ehrenbergina serrata.

Chilostomellidae besides Sphaeroidina bulloides are represented by the genera Chilostomella; sometimes Pullenia sphaeroides and Pullenia quinqueloba are found.

Of *Anomalinidae,* besides Planulina wuellerstorfi, Cibicides pseudo ungeriana and Laticarinina pauperata already mentioned, we find the species Cibicides lobatulus and Anomalina grosserugosa not infrequently.

Arenaceous Foraminifera are found in all kinds of deposits and at all manner of depths. Specimens of the families of the *Astrorhizidae* (including especially Rhabdammina irregularis), *Rhizamminidae* (often including Bathysyphon filiformis), *Reophacidae, Lituolidae, Textularidae, Verneuilinidae* (both Gaudryina scabra and Gaudryina bradyi) and *Valvulinidae* (including Martinottiella communis) were met with. The arenaceous Foraminifera were always found in small quantities. Broken parts of arenaceous Foraminifera are often met with.

The usually large Foraminifera from the families of the *Camerinidae* (Operculina, Heterostegina), *Amphisteginidae* (a.o. Amphistegina lessonii), *Calcarinidae* (Calcarina calcar, Baculogypsina tetraedra etc.), *Cymbaloporidae, Nonionidae* (Polystomella) and *Planorbulinidae* (especially Planorbulina larvata) occur chiefly on the shelves, in the Coral Muds or in the vicinity of limy coasts (St. 102, 110, 136, 186, 210 and 293) and of Coral Muds (St. 66, 73, 169 and 206). Foraminifera of the families *Homotremidae* and *Rupertidae* were only shown in Coral Muds.

Echinoderm fragments.

Of the other calcareous organisms the most common are echinoderm fragments. They occur in about $^2/_3$ of all the stations sampled, although they usually are found in small quantities, as the tables show. *Echini spines* especially, were often met with, they are present in sediments down to a depth of 5500 m. Fine whole echinoids were found in the Coral Muds 51 and 60.

Crinoid fragments.

Crinoid fragments were found only at St. 137.

Pteropods.

Of the Mollusca, Pteropods are the most widely distributed, they were shown in $^1/_4$ of the samples examined . The content of these organisms is low in most of the samples. The highest Pteropods content is found in the Globigerina Ooze 86, raised from a depth of 350 m, it amounts to 16%. It is somewhat lower in the neighbouring Globigerina Ooze 85 from 700 m depth. In the remaining samples the content of Pteropods is 3% or less. Thus there is nowhere a sediment which could be characterised as Pteropod Ooze.

Gastropods.

Gastropods are especially found in the sediments on the shelves (St. 25, 26, 28, 29, 37 and 91), in Coral Muds (St. 45, 51, 60, 67, 73, 124, 129, 165, 182^{L}, 206 and 352), or in the vicinity of coral banks and of limy coasts (St. 96, 102, 110, 133, 136, 137, 185, 186, 189^{III}, 328); further they are found in the Shallow Water Deposit 157 and in samples 104 and 283.

Miss W. S. S. van Benthem Jutting found representatives of the following genera: Mitra, Triphora, Murex, Turritella, Vexillum, Columbella, Cerithium, Capulus, Turris, Philbertia, Turbonilla, Trivia, Erato, Hemitoma, Rissoina, Scala, Lamellaria, Polynices, Vanikoro, Odostomia, Apicalia, Trochus, Liotia &c, &c.

Lamellibranches.

Lamellibranches were found in five samples which were raised from, or near the shelves (St. 25, 26, 28, 37, 91) in 2 Coral Muds (St. 60, 199), in the vicinity of limy coasts (St. 92, 102, 133, 136, 137, 186), in shallow water (St. 35^{L}, 157) and in three typical Globigerina Oozes (St. 85, 86 and

88). Those found were Venus (Timodea) marica L. juv., and the genera: Limopsis, Nucula, Leda Malletia, Arca, Cardita, Modiolus, Chama, Angulus, Lima, Pecten, Ostrea, Standella, Mactra, Cardium &c. &c.

Scaphopoda.

Scaphopoda were found by Miss W. S. S. van Benthem Jutting in a few samples of the genera Dentalium and Siphonodentalium.

Ostracode valves.

These were found in very small quantities in 30 of the samples namely in Coral Muds, Globigerina Oozes, in sediments from the shelves and in 5 Terrigenous Muds from close by the coast.

Otoliths of fish.

These are found in very small quantities in seven Coral Muds rich in lime, in 12 Globigerina Oozes and in 3 limestone detritus-bearing Terrigenous Muds.

Coral particles.

Coral particles are found in 18 sediments as clearly recognisable components.

Bryozoa.

These were met with in seven Coral Muds and 8 other sediments. The latter sediments have been formed either in the vicinity of coral reefs or limy coasts or in shallow water. The content of Bryozoa is remarkably high in the Coral Muds 60 and 182^L.

Alcyonarian spicules.

Alcyonarian spicules were shown in 48 sediments. They are found in the sediments down to a great depth, even in two from the deep Celebes sea. But only few of the sediments rich in lime contain a higher percentage of these organisms (0,6—2,7%).

The size of the Alcyonarian spicules varies usually between 0,1 and 1 mm. Sometimes they are coloured pink or purple.

Their appearance is almost always accompanied by the presence of calcareous Sponges.

Calcareous Sponges.

Calcareous Sponges were encountered in fully 50% of the samples examined. They are thus much more common than would be concluded from the description of the Siboga samples by Böggild (8). They are found in the sediments like the Alcyonarian Spicules, down to great depths. The calcareous Sponges are accompanying organisms in most of the Coral Muds and moreover usual in the Globigerina Oozes in which coral rock and limestone detritus are found. They occur in some of the other deep-sea sediments, especially in Terrigenous Muds, containing limestone detritus in greater quantities.

In table 28, in so far as data were at our disposal, the number of samples of each type of sediment (subdivided into coarse-grained (c) middle-grained (m) and fine-grained (f) sediments) are divided into 6 groups, according to the percentage $\frac{\text{calcareous Sponges}}{\text{calcite + calcareous debris}}$ of the fractions larger than 20 μ beeing more than 50 (I), 10—50 (II) or less than 10 (III) or there beeing no calcareous Sponges with a content of calcite + calcareous debris in the fractions greater than 20 μ = 0 (IV), smaller than 1% (V) or larger than 1% (VI).

From this table it may be seen that in the Coral Muds and the Globigerina Oozes the presence of calcite and calcareous debris is almost always accompanied by the presence of calcareous Sponges. The content of calcareous Sponges is moreover effected by the grain-size of the sediments, so that according as the diameter of the lime particles in the sediment increase the content of calcareous Sponges diminishes. In the Terrigenous Muds the relation of these two factors is less evident; while in Volcanic Muds few calcareous Sponges are found, which may be accounted for by the low calcium carbonate content of these sediments.

TABLE 28. The relation between the presence of calcareous Sponges in the sediments and the content and fineness of the calcite + calcareous debris.

% calcareous Sponges / calcite + calcareous debris	Coral Mud			Globigerina Ooze			Terrigenous Mud			Volcanic + Terrig. Mud			Volcanic Mud		
[1]	c.	m.	f.	c.	m.	f.	c.	m.	f.	c.	m.	f.	c.	m.	f.
I > 50			1	1	3	14			5					1	
II 10—50		3		2	5	6		5	8			5		2	
III < 10	5	1		7	1		2	5	16			2			
no calcareous Sponges:															
IV calcite + calc. debris = 0 . . .	3			5	3	8		1	17		2	21		13	1
V „ + „ „ = < 1% .					1	1		2	31		2	1		1	
VI „ + „ „ = > 1% .						1		5	1					1	

The highest content of calcareous Sponges occurs in Coral Muds and in the vicinity of coral reefs.

Coccolithes.

Coccolithes were found in only 10 samples and in very small quantities. That is to say that in 10 samples only the Coccolithes were larger than 20 μ, they may have been present in smaller size in the other samples, but no further research was made.

The Coccolithes in these 10 samples are always accompanied by Discoasteridae and calcite or dolomite rhomboedra.

Discoasteridae.

Discoasteridae were not reported by Böggild (8) in the sediments of the Siboga-expedition. They could be identified at 25 stations of the Snellius-expedition in the fractions 50—20 μ. These Discoasteridae coincide in general with the species described by Tan Sin Hok (156), which occur in limestones and marlstones of the Mollucca s. The most frequently met with was Discoaster Brouweri nov.spec.typ., to a less extent Discoaster Molengraaffi nov. spec. var. occurs. More rarely Discoaster Ehrenbergi nov. spec., Discoaster Barbadiensis nov.spec.var. Bebalaini, Discoaster Brouweri nov. spec.var. α and γ, Discoaster pentaradiatus and Discoaster „Coccolithe" of Brindisi after Schmidt (see bibl. 156) are found. The 6-limbed forms are the most common, but 5-, 7- and 8-limbed forms are also found. Moreover deviating varieties of the forms described are met with, which still need to be described. In researches carried out for this purpose it would be desirable to include the examination of fractions 5—20 μ of the samples from the Snellius-expedition for Discoasteridae. In the limestones and marlstones of the Moluccas, according to Tan Sin Hok the star-shaped Discoasteridae predominate, usually they are 6 rayed. On the other hand in Barbados the Helio-discoasteridae are frequent and in the star-shaped Discoasteridae the 8 rayed forms predominate.

From the examination of the sediments from the Snellius-expedition it appears that the same forms of Discoasteridae preponderate in the recent sediments of the seas which surround the Moluccas as in the limestones and marlstones occurring on the Moluccas.

It is not clear why the Coccolithes in the sediments from the Siboga-expedition could be shown and the Discoasteridae could not; the probable reason is simply that the Discoasteridae are less well known.

In 10 of the 25 samples which contain Discoasteridae Coccolithes were identified. In 17 of these 25 sediments calcite and dolomite rhomboedra were found with the Discoasteridae.

The Discoasteridae in these sediments occur at a depth of 400—4400 m. They are found chiefly in the vicinity of the Ceram Timor arc and of the Sawoe islands. Moreover sediment 200 is relatively rich in Discoasteridae.

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[1] c. = coarse, m. = medium, f. = fine.

Of the siliceous organisms the *Sponges* are most frequently met with, *Radiolaria* are seldom wanting, the content of *Diatoms* is always small, or they are entirely absent, in the sediments examined from the Neth. Indian Archipelago.

The total content of siliceous organisms varies very much, from a trace to 7,8%.

It is to be expected that the silicic acid concentration of the sea-water will effect the formation of silliceous organisms and that also the solution of these organisms will be dependent upon it.

Both in sea-water and river water a small amount of silicate is in solution. According to Harvey (72) p. 50 a seasonal variation has been observed in the English Channel and in the Baltic owing to its utilisation by Diatoms; in the former area a spring maximum of 200—240 mg SiO_2 per cubic metre has been ascertained to fall to 40 mg or less. In the Atlantic Ocean in the surface water 100—200 mg SiO_2 per cubic metre was measured, values of 360 mg SiO_2 per cubic metre having been found at 1000 metres and 1200 mg at 3000 metres.

The SiO_2 content of river water usually varies between 8 and 80 mg per litre, thus it is always higher than the values Harvey found for SiO_2 in sea-water.

It seems probable that the nature of the material that settles will effect the concentration of silicate in the sea-water and thereby the content of siliceous organisms in the sediments. For the time of settling for fine sand, dust and the clay fractions is considerably high, and the surface of contact with the sea-water increases per unit of weight with decreasing grain-size of the material, while the time of settling also increases with it. To ascertain the existence of this effect the sediments in table 29 are divided into groups according to the nature of the material deposited. For each of these groups the variation in the content of siliceous organisms and the mean content are calculated.

TABLE 29. Relation of the nature of the rock material of the sediments to the content of siliceous organisms.

Nature of material	number of samples	variation in % siliceous organisms	mean % siliceous organisms
Volcanic Mud	24	0,3 —7,8	2,08
Volcanic + Terrigenous Mud	45	0,2 —4,8	1,98
Acid Igneous Rocks (group II)	18	0,3 —7,24	2,03
Basic older Volcanic Rocks (group V)	48	tr.—5,61	1,48
Crystalline Schists (group I)	12	0,29—2,06	1,18
Metamorphic basic to intermediate Rocks (group III) .	50	0,08—3,16	0,84
Quartziferous sediments (group IV).	25	tr.—1,43	0,42
Total	222	tr.—7,8	1,41

From table 29 it appears that the mean content of siliceous organisms in the 4 first groups, that is the Volcanic Muds, the sediments mixed with recent-volcanic material, the sediments formed from acid igneous rocks and the sediments formed from basic older volcanic and igneous rocks, is higher than in the sediments which are formed from metamorphic rocks (group I and III) and that the mean content of siliceous organisms of the quartziferous sediments is the lowest. This is as might be expected, as quartz gives practically no SiO_2 in solution, in contrast to most silicates.

It is true that the difference of the content of siliceous organisms in the various groups is great, the maximum content of siliceous organisms, however, shows a similar sequence to the mean values. The great latitude in the content of each group must be ascribed to the effect of other factors, of which the settling velocity of the sediments is certainly the most important. Thus the lowest content, of 0,3%, is found in the Volcanic Muds in sample 245 A, i.e. in a layer of volcanic sand which must have been rapidly deposited, in contrast to the sediment lying beneath it, 245 B, which is composed of finer, but similar, recent-volcanic material and of clay. The lower stratum 245 B has a much higher content of siliceous organisms than 245 A.

In an area of rapid deposition, like the straits of Makassar, the sediments have also a low content

of siliceous organisms, it is extremely low in samples 33 A and 40. It is not impossible that sample 33 A may be composed of precipitated material.

Other sediments, of which it is probable or possible that they are composed of material slid down the slope, such as samples 182, 98, 271 and 362, also contain very low percentages of siliceous organisms. A contrast in content of siliceous organisms is shown in the Globigerina Ooze 106 B (0,4%) and the lower layer of Terrigenous Mud 106 A (tr.) which is probably formed by material slid down the Sahoel flat. The content of the upper layer 106 B corresponds to the mean content of siliceous organisms for quartziferous sediments, in the lower layer it is very small.

The content of siliceous organisms of the sediments in shallow water is also low. These sediments, however, are usually formed by material containing a large amount of quartz, or by coarse sandy material (St. 35^L, 60, 182^L), i.e. by material with a small contact surface with the surrounding medium, in this case the sea-water.

To sum up it may thus be said that the nature of the material deposited in a particular area certainly forms one of the factors determining the content of siliceous organisms of the sediment in that area. A second important factor is of course the settling velocity of the sediments.

The content of *Sponges* varies from a trace to 7,3%, of *Radiolaria* from 0 to 6,7% and of *Diatoms* from 0 to 0,6%.

While the content of Sponges in the sediments does not seem to correlate with the depth at which they are deposited, the higher content of Radiolaria in the East Indian Archipelago occurs only at greater depths (see table 30), just as Radiolarian Ooze in the great oceans is only formed far from the coast at great depths.

As the Diatom Oozes only occur in cold seas with low salinity of the water, in contrast to the Radiolarian Oozes, it is not surprising that in the sediments of the East Indian Archipelago no, or only low contents of these organisms are met with.

TABLE 30. Relation of the depth to the Radiolaria content of the sediments.

Depth	Variation in Radiolaria content	number of samples
20— 360 m	0,00—0,02%	10
380— 650 „	0,00—0,2 „	21
660— 970 „	0,00—0,6 „	14
1000— 1500 „	0,00—0,8 „	25
1500 —2000 „	tr.—1,6 „	17
2000— 3000 „	tr.—1,8 „	56
3000— 4000 „	tr.—2,6 „	31
4000— 5000 „	0,01—3,8 „	27
5000— 6000 „	0,2 —6,7 „	17
6000— 7000 „	3,0 „	1
7000— 8000 „	tr.—0,6 „	3
8000—10000 „	0,2 „	1

In these sediments, as in the Radiolarian Oozes which are confined to the warm tropical seas, the box-shaped Coscinodiscus is by far the most common Diatom. In a limited number of samples, moreover, Diatoms of the genera Triceratium and Navicula are found; while in a few samples Diatoms of the genera Surirella, Hemidiscus, Arachnoïdiscus, Auliscus and Actinoptychus were identified.

CHAPTER VIII

SECONDARY MINERALS

The principal secondary minerals found were pyrite, barite, glauconite, limonite, manganese oxides and calcite or dolomite rhomboedra. Phillipsite, which is often found in deep-sea deposits, could not be identified in the Snellius samples.

Pyrite.

Pyrite was identified in a great number of the sediments from the East Indian Archipelago, viz. in 72% of the Terrigenous Muds, in 61% of the Terrigenous + Volcanic Muds, in 62% of the Globigerina Oozes, in 50% of the Coral Muds and Shallow Water Deposits and in 18% of the Volcanic Muds.

The pyrite is usually found as blackish brown globules, which occur singly or in aggregates. These aggregates partially fill the chambers of Foraminifera or other organisms (see photo 27 and 28). More rarely they are found on Radiolaria and Diatoms. Yellow pyrite with a metallic lustre and distinct crystal faces was found only in samples 87, 88, 106 A, 119, 257 and 328.

The formation of pyrite takes place principally in the deeper layers of the sediments, as may be seen from the pyrite content of the samples in table 31.

TABLE 31. Pyrite content in different layers of deep sea sediments.

station	layer	% pyrite
106 B	upper	0,03
106 A	lower	1,2
189 I	0— 11 cm	0,18
189 III	12— 23 cm	0,65
189 IV	23— 30 cm	0,60
189 V	30— 35 cm	0,55
193 E	10— 15 cm	0,00
193 A	170—174 cm	0,18
215	30— 70 cm	0,00
215 A	70— 80 cm	0,07
218	0— 30 cm	0,00
218 A	70— 79 cm	0,2
330 A	0— 6 cm	0,03
330 B	100—106 cm	0,7
330 C	146—152 cm	1,2
331 A	0— 6 cm	0,03
331 B	80— 86 cm	0,1
331 C	181—187 cm	0,55
347 B	0— 6 cm	0,1
347 C	80— 86 cm	1,0
347 A	170—176 cm	1,3

This condition corresponds completely with the observations by other research workers. As early as 1886 van Bemmelen (6) in his research on old marine clay from the Netherlands alluvium observed that the pyrite occurred in the deeper layers. Correns (37) reports that the Blue Muds in the Atlantic ocean have a thin brown upper layer, which indicates that in this upper layer the anaerobic conditions, necessary to the formation of pyrite, are absent. The pyrite content in these sediments is low, varying from 0,04% to 0,25%, while Correns was unable to identify any pyrite microscopically.

On the other hand the microscopically visible pyrite-content of the Snellius samples reaches a maximum of 3.8%. This fact indicates that the conditions necessary to the formation of pyrite are more favourable in the basins and troughs of the Netherland Indian Archipelago than in the open oceans. And yet some of the pyrite-bearing Snellius samples have a thin brown upper layer.

It is generally assumed that pyrite and marcasite owe their origin to the reduction of iron salts by organic compounds. Through the decomposition of the sulphur-containing organic matter hydrogen sulphide would be released. (As far as I am aware no research has been made as to whether in deep-sea sediments sulphate reducing bacteria play a part in the formation of hydrogen sulphide from sulphates).

The hydrogen sulphide, with ferric hydroxide, forms ferrous sulphide and sulphur according to the equation:

$$3H_2S + 2Fe(OH)_3 \rightarrow 2FeS + S + 6H_2O$$

Miss J. A. D. Verhoop (169) has demonstrated that the blue-black colour of the muds is due to ferrous sulphide. She further demonstrated that „the formation of iron pyrites out of ferrous sulphide and elementary sulphur is a purely chemical reaction, taking place under anaerobic conditions", that is, without the need of the co-operation of micro-organisms.

$$FeS + S \rightarrow FeS_2$$

Andrée (2) reports on p. 112 that Doss found in some soils an unstable form of FeS_2, called Melnikowit, which, in contrast to pyrite, is soluble in dilute hydrochloric acid. This Melnikowit is presumed to be derived from a bi-sulphide gel; Andrée ascribes the frequent formation of pyrite in the form of globules to the appearance of this hydrogel.

As anaerobic conditions are necessary to the formation of pyrite, it is natural that in the basins of the Netherlands Indian Archipelago where the rate of sedimentation is higher than in the open oceans, pyrite formation takes place to a greater extent, as the sediments are more easily reduced than those slowly settling; at the same time the higher content of organic matter in the basins facilitates the formation of pyrite, as will be seen later. Moreover this accounts for the pyrite being particularly formed in the organisms where anaerobic conditions will sooner occur, while organic matter which may be present will accelerate the formation. The fact that pyrite is absent from the sediments in straits, in the eastern Celebes sea and western Molukken sea, as well as in the sediments of submarine ridges, all of them places where there are stronger currents than in most basins and troughs, shows very clearly how the formation of pyrite depends upon the velocity of the renewal of the water above the sediments. Kuenen has reported a case of stagnant water, even containing hydrogen sulphide, in the Kaoe basin, in section 1 of this volume. The sediments in this bay all proved to contain more than 1% pyrite.

The examination of the Snellius samples confirms the well known observation that pyrite is seldom found in coarse-grained sediments. In the Globigerina Oozes, Coral Muds and Volcanic Muds which contain more than 50% coarse sand, no pyrite was found, any more than in the few coarse-sanded Terrigenous Muds.

Relation of the carbon and nitrogen content to the pyrite content of the sediments.

As the organic matter plays a part in the pyrite formation, we investigated whether a connection could be traced between the C- or N-content of the sediments, which Trask determined (see section 1) and the presence of pyrite.

It proved that of 86 sediments in which the C-content was determined, 35 with a carbon content of less than 1,0% contained no pyrite, or only a trace, of 40 samples with a carbon content between

1,0% and 2,0% 20 did and 20 did not contain pyrite; the 11 sediments with a C-content greater than 2,0% all contained pyrite.

For the nitrogen content of the sediments we have the following figures: below 0,05% N no pyrite and above 0,2% N always pyrite.

It thus appears definitely that there is a relation between the content of organic matter and pyrite in the sediments.

The relation of depth to the pyrite content of the sediments.

In table 32 the occurrence of pyrite in the deep-sea sediments is treated in connection with the depth. A distinction is made between the sediments in the basins and troughs of the East Indian Archipelago and in the open Oceans.

TABLE 32. The relation between pyrite content and depth.

Depth in Metres	Number of samples containing pyrite		Number of samples without pyrite	
	in basins and troughs	in open oceans	in basins and troughs	in open oceans
0—1000	37		15	
1000—2000	36		23	
2000—3000	29		13	2
3000—4000	21		11	1
4000—5000	8	1	12	1
> 5000	10	1	5	6

From this table we see that there is no relation between the pyrite content of the sediments and the depth at which they are deposited. The observation is confirmed that there is more pyrite formed in the basins of the East Indian Archipelago than in the open oceans.

For each depth pyrite was identified in about $^2/_3$ of the sediments, with the exception of 4000—5000 m. The latter must be regarded as an accidental circumstance as in this group 8 pyrite-free sediments from the eastern Celebes sea occur.

Thus to summarise it may be said that pyrite in absent from most of the Volcanic Muds, from the areas of scanty sedimentation and from those areas where there is a rapid renewal of the water or very coarse-sanded sediments occur. The formation of pyrite is facilitated by a high settling velocity, by a high content of organic matter and by a slow renewal of the water.

The method of research applied by Böggild (8) is probably the cause of his identifying a lower percentage of pyrite in the Siboga samples than the present author has found in the Snellius samples.

Barite.

This mineral, with pyrite, has been identified only in the Globigerina Oozes 87 and 88 in very small quantities. Böggild (8) found barite concretions in the Blue Mud S. 253.

Glauconite.

Glauconite was found at 65 Snellius stations though in greater quantities, varying from 4.0% to 11.4%, at only 9 stations.

Murray and Renard (115) had already proved that glauconite formation takes place in the vicinity of continents free from large rivers, where steep primeval solid rocks formed the coast and where sediments accumulate at a slow rate. Glauconite is usually not found near volcanic islands. This applies also to the Snellius samples; the glauconite-bearing sediments are principally found along the west coast of New Guinea and along the Sahoel shelf (taken from Waigeo to Rotti), along and upon the Soenda shelf, by the Spermonde shelf, by South Celebes and the islands to the east of it, north of Soemba and upon or near the Soeloe Archipelago. The high glauconite contents are found in the sediments by New Guinea and the Sahoel shelf, and upon or near the Soenda shelf.

Murray and Renard consider the most favourable depth for the formation of glauconite to be 400—600 m although they could demonstrate smaller quantities of glauconite in sediments down to 4000 m depth. In the Snellius samples the 9 samples with a glauconite content of 4,0—11,4% occur at a depth of 250—750 m; in 5 sediments with a glauconite content of 0,7—2,8% the depth varies from 80 to 1450 m; in 51 sediments with a glauconite content of a trace —0,45% the depth varies from 60 to 4450 m; corresponding, therefore, to the observations of Murray and Renard.

The above authors consider that the presence of organic matter is an essential condition for the formation of glauconite. The Snellius samples did not demonstrate a relation between carbon and nitrogen content to the glauconite content, it must not be forgotten, however, that the carbon and nitrogen content was only determined in 23 of the glauconite-bearing samples.

In 50 of the 65 glauconite-bearing samples pyrite was found; the presence of glauconite together with pyrite in sediments is a phenomenon recorded by many writers.

Murray and Renard considered that glauconite formation took place only in the chambers of organic skeletons. Collet and Lee (36) pointed out, however, that glauconite may occur not only as glauconitic casts but also as glauconitic grains produced by the glauconitisation of faecal pellets and as pigmentary glauconite.

Glauconite formation, therefore, does not seem to be confined to the chambers of Foraminifera and other organisms, although glauconitic casts are the most usual form it takes. This applies also to the Snellius samples. The Snellius samples, which have a high glauconite content, are Globigerina Oozes with a high content of unblemished Foraminifera, the glauconitic casts can be observed in them. Of the Siboga samples which Böggild (8) examined, the sediments with a high glauconite content are Coral Muds and Globigerina Oozes, containing many organisms in the sand fractions. The correlation of the glauconite content to organisms is more distinct than with the calcium carbonate content which Böggild reports. Of the Snellius samples, containing glauconite, 34 are Globigerina Oozes, 3 Coral Muds and 28 Terrigenous Muds.

Murray and Philippi (116) are of opinion that glauconite occurs particularly where cold and warm currents meet. The Snellius samples supply no data for forming an opinion on this subject, unless the sparse occurrence of glauconite in the sediments of the eastern Netherlands Indian Archipelago should be attributed to the rarity of cold currents at the depths required for glauconite formation.

Hadding (64) has given a survey of the various theories on the origin of glauconite, a silicate of potassium and ferric iron. The possibility of its development from clay-minerals (filling the cavities of Foraminifera), faecal pellets and silicate mineral substances, such as volcanic glass, felspars, mica, amphiboles or pyroxenes are discussed. The process of formation of glauconite is still an unsolved problem. Hadding himself favours the opinion that glauconite is formed as a flocculent precipitate on the sea floor, and not by the conversion of pre-existing minerals. The present author has not made any investigation of the exact origin of glauconite, but it should be accentuated that in the area where glauconite formation is most frequent, namely, by New Guinea and the Sahoel shelf, a mineral „X" is found, which has been described as far as is possible in Chap. IV, and usually occurs in the company of glauconite. It is possible that this mineral is an intermediate product or a by-product of the glauconite formation, as it occurs only in the shells of organisms. Moreover in the chambers of Foraminifera of sediments containing much glauconite, such as the Globigerina Ooze 88, colourless fibro-radiate aggregates were observed in larger quantities. These aggregates were not further examined, they belong to the light crop. An examination of these kinds of aggregates, however, might throw interesting light upon the formation of glauconite.

Limonite

Limonite occurs chiefly as a component of the casts of Foraminifera and other organisms, it is found much less as flaky limonite or as a cementing medium in arenaceous Foraminifera.

Limonite is often found in the sediments together with glauconite or pyrite, sometimes also in company with ferro-manganese oxides. Pyrite cores with a coating of limonite occur in sediment 257. The limonite content of the sediment seldom exceeds 0,5%, a slightly higher content is found in sediments 87, 91, 92, 228, 257, 355 and 200. Ferruginous pellets were found only in sediments 328 and 355.

An exceptionally high content of ferric oxides is found in the substratum of 28—55 cm at station 194, that is in the Red Mud 194A; this material may be derived from a sliding or precipitation of material from the volcano Batoe Tara, and been weathered to red soil while still on land. At no other station such a high content of ferric oxides was found. Probably, therefore, the ferric oxides in this sediment are not secondary minerals formed in the sea-water. It is also possible that the flaky limonite in a few other Volcanic and Terrigenous Muds is derived from the land.

Where the limonite forms a part of the casts of organic skeletons, which is usually the case, it may be considered as a secondary mineral. This limonite formation seems as if it might be related to the pyrite and glauconite formation, as well as to a direct oxydation from the minerals in the sediments, as indicated by the occurrence of limonite-bearing sediments at places where there are strong currents and its appearance together with ferro-manganese oxides.

There proved to be no connection between the appearance of a brown upper layer and the limonite content of the sediments.

Manganese oxides

Manganese nodules, or a film of manganese on pebbles, sand, marl, Corals and Balanidae are reported by Kuenen (table 2) in various coarse deposits. Examination of the sediments under the microscope revealed deposition of manganese in only an occasional finer sample. The deposition of manganese takes place chiefly in sediments lying in straits or upon ridges and banks where strong currents run, so that there is a rapid transport of well oxygenated water. Manganese nodules can also be detected in the Red Clay 263. Only small concretions were found, which cannot be compared with the large manganese nodes found by Murray and Renard in the open oceans, and which, according to the inclusions of fossil fragments from the tertiary age (e.g. shark teeth) required a very long time for its formation.

The occurrence of manganese oxides in sediment 355 lying on the slope from Misool to the Ceram sea, is very remarkable. The manganese oxides in this sample have been deposited in the ferruginous pellets and in the limonite-bearing clay casts, where the ferric oxides greatly predominate.

East of St. 355 the Siboga expedition, at S. 177 S.W. of Misool, found corals and pebbles covered with manganese oxides; even the lime of the corals themselves was partially substituted by these manganese oxides.

The deposition of manganese at these two stations in the Ceram sea forms an indication that here a strong bottom current runs, especially at the Siboga station where no fine sediment was brought up.

Correns (37), in contradiction to Murray and Renard (115), is of opinion that considering the extremely small content of manganese in the sea-water, the manganese crusts cannot be formed by precipitation from the sea-water. He therefore considers manganese crusts to have been formed by the leaching of volcanic glass, minerals and rock particles containing this element. The manganese would diffuse to the surface of the rocks and mineral particles as a concentrated solution of chlorides and sulphates, where it would be transmuted into hydroxide by relatively well oxygenated sea-water and as such be precipitated in colloidal condition by the high salinity of the sea-water. It is not impossible to imagine that manganese might be precipitated in this way, but it cannot be assumed that in the process concentrated manganese solutions would occur on the surface of the rock particles, as the manganese would only be very slowly dissolved out of the rock and might diffuse in the sea-water also. Neither would this account for the formation of manganese crusts upon Balanidae and Corals, which certainly have not a high manganese content; moreover it would remain entirely inexplicable how the lime of Corals could be replaced by manganese dioxide, as observed on the Siboga-expedition at station 177. It must therefore be assumed that precipitation of manganese from the sea-water is possible.

Calcite and dolomite rhomboedra

The sharp-sided rhomboedra of calcite and dolomite are secondary formations which were found in the sediments at 63 of the Snellius stations, in quantities varying from a trace to 0,3%. Larger quantities occur in samples 354 A and 375; in 375 they are chiefly calcite rhomboedra. All

sediments in which they were found are deposited in the vicinity of coasts where there is much limestone or near coral reefs. In 50 of the 65 sediments in which they were found the limestone or coral lime detritus could be identified. It appears, therefore, that here a transmutation or accretion of particles of fine-grained calcareous mud takes place. These sediments occur N.W. of Misool, in the Ceram, Arafoera and Timor seas, along the inner side of the Ceram-Timor arc, by Rotti, Savoe and East Soemba, by the coast of N.W. Flores (St. 182), by the Toekang besi islands, in the Soeloe sea, in the western Celebes sea, by the Mandar coast of West Celebes and in sediment 265 near Mindanao. The depth at which these sediments are deposited varies from 350 to 5500 m. The Siboga-expedition found dolomite concretions near the E.point of New Guinea; between the Kei islands and by Aroe; dolomite rhomboedra are not reported.

SUMMARY

CHAPTER I

Method of Research

The mechanical analysis of bottom samples according to Mohr's method is briefly explained in this chapter.

In the mineralogical examination of the samples the six sand fractions in each sample as they were obtained from the mechanical analysis, were examined separately. The field-counting was applied to the microscopical examination of the sand fractions. The inadequacy of a research for the heavy minerals only in the case of samples from the eastern Netherlands Indian Archipelago and the necessity of a complete examination of the minerals and organisms contained in them, are set forth in this chapter.

CHAPTER II

The sediments from the Netherlands Indian Archipelago are divided into six principale types: Globigerina Ooze, Coral Mud and Sand, Red Clay, Terrigenous Mud, Volcanic Mud, Volcanic+ Terrigenous Mud.

Globigerina Ooze embraces the sediments which contain more than 30% $CaCO_3$, the greater part of which consists of pelagic Foraminifera.

Coral Sand and Mud contain coral lime detritus; they show a great variation in the composition of the calcareous constituents.

Red Clay is a sediment usually deposited at a great depth and far from land, reddish brown in colour through settling slowly in well oxygenated water, containing manganese concretions and consisting chiefly of terrigenous material.

The term Terrigenous Mud corresponds to the Blue Mud of Böggild and includes the Blue Mud and Green Mud of the Challenger-expedition. The green colour, namely, shown by some 20 of the Snellius samples proved to be unconnected with a high glauconite content, so that they cannot be termed green glauconitic muds; these 20 samples can therefore be better included in the Blue Muds.

The sediments which formerly, as the result of a sand examination only, were classified as Volcanic Muds, are here divided into Volcanic Muds, which consist for 50—80% of recent-volcanic material, and Volcanic + Terrigenous Muds, containing less than 50% (in the Snellius samples examined 3—30%) recent-volcanic material with moreover chiefly clay particles of terrigenous origin, as shown by the röntgenographic examination of the clay particles and by their mechanical composition (cf. also Chapter VI).

The term „ontkalkt diepzeeslik" introduced by Molengraaff in 1922 for lime-poor sediments which are not deposited far from the coast at depths greater than 4000 m, has not been maintained as in the Netherlands Indian Archipelago, lime-poor sediments are not confined to great depths. Moreover the poverty in lime of the sediments is due to the high settling velocity of recent-volcanic or terrigenous material and to the solution of the lime by cold, well oxygenated currents which renew the water in the basins. The sediments recorded by Molengraaf as „ontkalkt diepzeeslik" are therefore either Volcanic Muds or Terrigenous Muds or else Volcanic + Terrigenous Muds.

There is no reason for giving the deep-lying lime-poor sediments a separate name, especially now that the röntgenographic examination has demonstrated that the clay fractions of the sediment in a particular region are all of the same composition whether they are Globigerina Ooze,

Red Clay, Terrigenous Mud or Volcanic Mud. Thus the idea that Red Clay and Terrigenous Mud are formed in a very different manner proves to be a fiction.

The subdivision of the principle types in accordance with the mineralogical composition of the sediments is treated in chapter IV.

CHAPTER III

In earlier researches samples were collected in the eastern part of the Netherlands Indian Archipelago by the „Cachelot" (1858), the Challenger-expedition (1874), the „Gazelle" (1875) and the Siboga-expedition (1899—1900). From the Java sea in 1918 and the following years bottom-samples were collected which were examined chiefly for their mechanical composition. As far as possible the results of the examination of these samples have been made use of in the construction of map I. They are re-classified in this map, taking into account the present views on the formation of the sediments and the definitions of the above named principle types.

CHAPTER IV

The results of the microscopic examination of the sediments are given in this chapter.

The Snellius samples represent about 150% increase in the number of sampling places. It is therefore not surprising that the appearance of map I is very different from that of Böggild or of Molengraaff. The scheme of the sampling was still not close enough however, to make an exact demarkation between the types of sediment possible, Globigerina Ooze and Coral Mud in particular may prove to have a wider distribution than could be ascertained from the material at our disposition.

On map I the principle types are indicated by different colours. The sub-division of the terrigenous material according to the mineralogical composition is indicated by different shades of purple. The shading is continued in the regions where recent-volcanic and terrigenous material are combined. On this map no subdivision is made of the Volcanic Muds according to the volcano from which they originate.

The *Volcanic Muds* and the *Volcanic + Terrigenous Muds* are grouped around the recent volcanoes principally in two regions, namely in a region which follows the range of volcanoes from Java to the Banda Api and in a region embracing large parts of the Celebes sea and the Molukken sea. Further, to the west of the Oena Oena volcano in the Madoera strait Volcanic + Terrigenous Muds are met with. From the mineralogical and mechanical composition of the majority of the recent-volcanic material, the volcano from which it had originated could be determined. We could demonstrate eruption products of the Tambora, the Rokatinda on Paloeweh, the Sangean Api, the Batoe Tara, the Flores volcanoes, the volcanoes on Lomblèn, the Gg. Api north of Wetar, the Woerlali on Damar, the Seroea, the Banda Api, the Doekono, the Roeang, the submarine volcano Banoea Woehoe, the Gg. Awoe on Sangih, the Lokon or Sopoetan and the Oena Oena. The eruption products of the Tambora, of which there was a terrific eruption in 1815, and from the Sangih volcanoes: Roeang, Banoea Woehoe and Gg. Awoe are the most widely distributed.

The distribution of Tambora ash did not prove to correspond to the elliptical region given by Zollinger in connection with the east wind which he considered to prevail (cf. map. II). In reality the direction as well as the force of the winds vary, which is considered the principle reason of the actual area of distribution of the Tambora ash deviating largely from the ellipse.

The research has shown that marine currents have a great effect upon the distribution of the products of the Tambora and Sangih volcanoes in particular. Distribution of the products to a great distance from the Sangih volcanoes should be attributed more to these than to aeolian distribution.

The marine currents effect the rate of settling as well as the distribution of the volcanic ash, the former being considerably retarded by it, Tambora ash proves to be still deposited after 115 years. Much more extensive observations upon the marine currents and the renewal of the water in the basins will be necessary to be able to account for the distribution of the volcanic ashes observed in the Flores sea, the Celebes sea and the Banda sea.

The sediments in these areas surrounded as they are by volcanoes, vary greatly in composition in the vertical direction, both in the content of volcanic ash and the nature of the ash, depending on the activity of the recent volcanoes.

One of the difficulties in comparing the mineralogical composition of the volcanic ash in the deep-sea sediments with the composition of the eruption products is that most geologists only analyse the composition of solid rock and pay little or no attention to the ash of the various eruption periods, although the composition of the ash is a much more constant factor.

The *Terrigenous Muds* are the most general deposits in the eastern Netherlands Indian Archipelago. They are divided into 5 groups, according as the terrigenous material is principally detritus of crystalline schists, acid igneous rocks, basic to intermediate metamorphic rocks, quartziferous sediments or basic old volcanic rocks, again to be divided into alkali-rocks and calc-alkali-rocks. The purple shading which indicates the various groups of Terrigenous Muds in map I is continued in other types of sediment which contain terrigenous material.

The mineralogical investigation is not sufficient for the classification of very fine sediments, in these cases a röntgenographic examination would be desirable, especially as in transport over a long distance the sand fractions and fine fractions of a sediment may contain material derived from different sources.

Both in ascertaining the volcano from which the recent-volcanic material is derived and in examining the origin of the terrigenous material, the mechanical composition of the sediments plays an important part, as material of the same mineralogical composition usually diminishes in mean grain-size with increasing distance from the coast of its origin, which is not necessarily the most proximate coast.

In the terrigenous sediments the composition may vary also in the vertical direction, e.g. consequent upon rapid deposition of material carried by flooded rivers which may be of a different mechanical and mineralogical composition to the more steady supply of fine-grained material in the dry seasons of the year. But the vertical variation is not a rule in Terrigenous Muds as it is in the Volcanic Muds. Strong differences usually occur in the vicinity of the coast.

Most of the Terrigenous Muds proved to be composed of detritus from the surrounding islands. No satisfactory indications of the process of formation could be obtained for the medium-grained sediments 104, 358 and 362 in the deeper part of the Aroe basin, the Banda sea and the Weber deep. A more extended sampling would be necessary here to understand the distribution of the material and to account for the deposit of these fine sandy sediments just in the deepest parts of the larger basins, as well as to establish the origin of the material.

Strong bottom currents may occasion a scanty sedimentation or none at all and expose a hard bottom or a fossil sediment. This usually occurs on or near the sill of the basins. In some areas, such as the eastern Java sea, the scanty sedimentation is due to a limited supply of terrigenous material.

A small number of sediments (98, 106A, 182, 260 and 271) seem to have been formed entirely or partially of material from submarine ridges or shelves. The hard bottom met with at stations 196, 270 and 357 may also have been caused by sliding off of material from the steep incline upon which these stations lie. Considering the mineralogical composition of sediment 260 and 271 lying near to St. 270 it seems possible that the Snellius ridge and the Nanoesa islands form a petrographical unity with the eastern cordillera of Mindanao. The collection and examination of the solid rock met with at St. 270 would be of great interest from this point of view.

Globigerina Ooze occupies a larger space on map I than in Böggild's map, as the Snellius-expedition covered areas not previously sampled.

The factors which determine the lime-content of the sediments are dealt with under that heading. The opinion of Molengraaff was confirmed, that the lower lime-content of the sediments in the basins, compared to those of the open oceans, is principally due to the more rapid rate of settling of terrigenous and recent-volcanic products. Moreover strong currents at low temperature diminish the lime-content of the sediments. Contradictory factors or the vicinity of lime-rich coasts and coral reefs occasion the formation of sediments with a lime content approaching that of the open oceans. The relative lime content of the sediments compared to the mean lime content in the eastern Netherlands Indian Archipelago and that of the open oceans is given on map III.

Typical Globigerina Oozes are deposited with a medium current velocity, usually upon ridges and shelves; they are of characteristic mechanical composition, determined by the size of the Foraminifera.

Coral Sand and *Mud* are undoubtedly further extended than given in Plate I where only those spots are marked where deep-sea research has been made.

The encounter of *„hard bottom and coarse deposits"* is usually connected with strong bottom and sill currents, the sliding of material is only seldom responsible for it.

The *mechanical composition* of the sediments in the easterly Netherlands Indian Archipelago in contrast to other areas described, is often more effected by the nature of the material contributed to the sediments and by marine currents than by the bottom configuration. In various cases a definite connection can be traced between the mechanical composition of the sediment and the distance from the volcano or coast from which its material is derived. The composition of the sea-water and the fauna also effect the mechanical composition of the sediments.

CHAPTER V.

In sufficiently long cores of Globigerina Ooze from that part of the Indian Ocean which surrounds the eastern Netherlands Indian Archipelago layers free from Globorotalia Menardii were never found. In contrast to the observations of Schott in the equatorial Atlantic Ocean, therefore, no indications are found here of the presence of a modified climate during the latest glacial period.

The settling velocity of Globigerina Ooze in the Netherlands Indian Archipelago shows no important deviation from that in the equatorial Atlantic ocean; while on the contrary the rate of sedimentation of Terrigenous Mud is here much more strongly varied and in the deep parts of most of the basins and troughs it is considerably higher than in the open oceans. The rate of sedimentation of some Globigerina Oozes and Terrigenous Muds could be calculated from the lower limit of the Tambora ash of 1815, or of the Oena Oena ash of 1898, being clearly observed in the sediments.

CHAPTER VI.

The röntgenographic examination demonstrated that the clay fractions of a sediment show quantitative variations in their composition and that the clay casts correspond most nearly in their composition to the fraction 2—0,5 μ. In contrast to the case of Terrigenous Muds, the clay fractions of Volcanic Muds have no relation to the composition of the sand fractions. The clay fractions of the Volcanic Muds proved to consist chiefly of terrigenous components and carbonate. The mechanical composition, therefore, gives indications of the content of terrigenous material in the Volcanic Muds and the Volcanic + Terrigenous Muds.

CHAPTER VII.

The calcareous organisms in the sediments, that is Foraminifera, Echinoderm fragments, Crinoid fragments. Pteropods, Gastropods, Lamellibranches, Scaphopoda, Ostracode valves, Otoliths of fish, Corals, Bryozoa, Alcyonarian spicules, calcareous Sponges, Coccolithes and Discoasteridae, are treated briefly in this chapter.

The *Pteropod* content of the sediments proved to be at most 16%, there is therefore no Pteropod Ooze.

Calcareous Sponges are much more widely distributed than had appeared from earlier researches. There proves to be a relation between the appearance of calcareous Sponges and the presence of calcite + calcareous debris in lime-rich sediments, therefore there is probably a relation to the degree of saturation of the sea-water in which the sediments are deposited with respect to calcium carbonate.

Discoasteridae were demonstrated for the first time in recent deep-sea sediments. They are found at a depth of 400—4400 m. The majority of the recent species met with correspond to those which have been described by Tan Sin Hok from the chalk and marl-stones of the Moluccas. Varieties were also found differing from the forms described, of which a description would be useful.

The content of *siliceous organisms* in the sediments proved to be in relation to the nature of the material deposited, in casu its capacity to deliver dissolved silica, and with the settling velocity of the sediment.

Higher percentages of *Radiolaria* only occur in the sediments from greater depths, while the content of *Sponges* has no relation to the depth.

CHAPTER VIII.

Of the secondary minerals *pyrite* is of much more frequent occurrence than in the open oceans, consequent upon the higher content of organic matter and the higher settling velocity of the sediments in most of the basins and troughs. A relation could be shown between the C and N content of the sediments and the occurrence of pyrite. Pyrite is absent in coarse sandy sediments, in most of the Volcanic Muds, in the areas of sparse sedimentation and those in which rapid renewal of the water takes place.

Barite was demonstrated in two samples only.

Glauconite was found in 65 of the Snellius samples but only in 9 samples in any quantity. The established conditions for the formation of glauconite were confirmed. The correlation of glauconite content and the content of organisms is more obvious than of glauconite content and lime content.

It is desirable that a research should be instituted into the nature of the colourless fibroradiate aggregates and the mineral „X" found in the Foraminifera shells of glauconite-bearing sediments which may both be intermediate or by-products of glauconite formation.

Secondary *limonite* occurs in small quantities in the sediments, as well as *manganese oxides*.

Calcite and *dolomite rhomboedra* are usually found in small quantities in the sediments deposited in the vicinity of lime-rich coasts or coral reefs.

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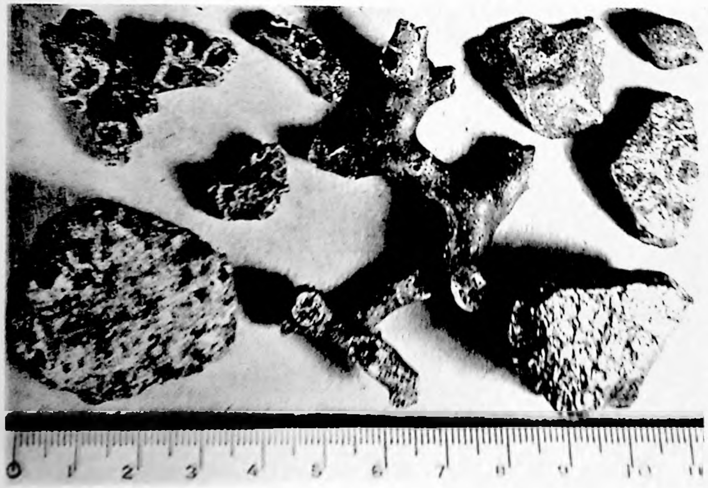


Photo 1. St. 295. N. of Talaud. — Deep-sea corals and angular fragments of lava with film of manganese.

Photo 2. St. 250. Manipa Strait. — Coarse and fine angular gravel (mica shist etc.) with film of manganese.

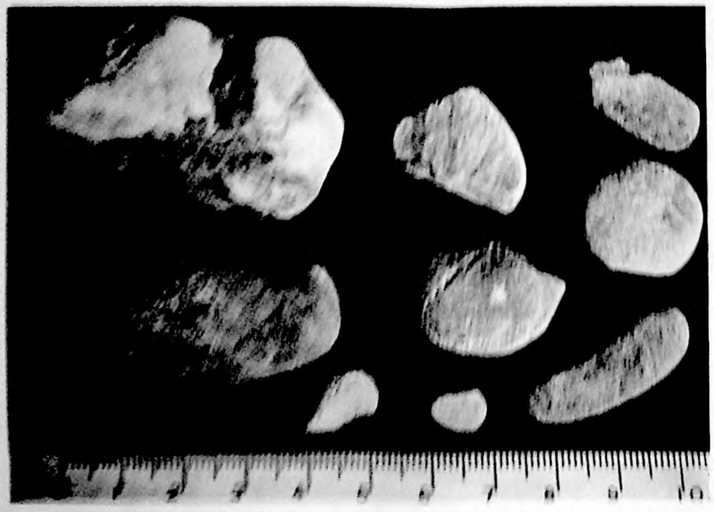


Photo 3. St. 272. S. of Boeroe. — Rounded gravel (quartz, shist etc.).

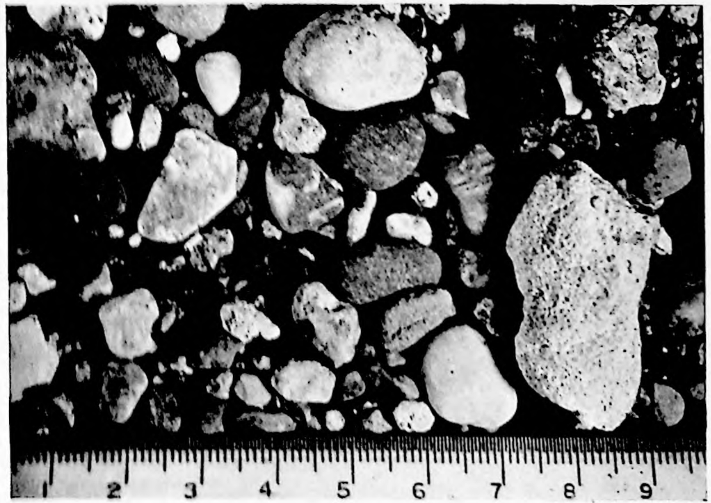


Photo 4. St. 211. S.W. of Boetoe. — Coarse and fine, rounded gravel and some fragments of shells.

Photo 5. St. 326. Ceram trough. — Fine gravel and sand with some foraminifera and fragments of shells and corals. (3,5 ×).

Photo 6. St. 351L. Bay of Mamoedjoe. — Coarse sand with few benthonic foraminifera, fragments of shells and organic matter. (3,5 ×).

Photo 7. St. 278. Kaoe Bay. — Terrigenous Mud.
Stratified sample, see description. (6 ×).
Photographed surface parallel to sea floor.

Photo 8. St. 25, lower part of sample. — Java sea. —
Terrigenous Mud. (20 ×).
Photographed surface parallel to sea floor.

Photo 9. St. 85. E. of Batjan. — Typical Globigerina Ooze with shells and Pteropods. (6 ×).

Photo 10. St. 86. E. of Batjan. — Globigerina Ooze, containing ± 16 % Pteropods. (10 ×).

Photo 11. St. 138. Dao Strait. — Typical Globigerina Ooze. (14 ×). Photographed surface parallel to sea floor.

Photo 12. St. 29, upper part of sample. Makassar Strait. — Typical Globigerina Ooze. (10 ×).
Sea floor parallel to lower side of photograph.

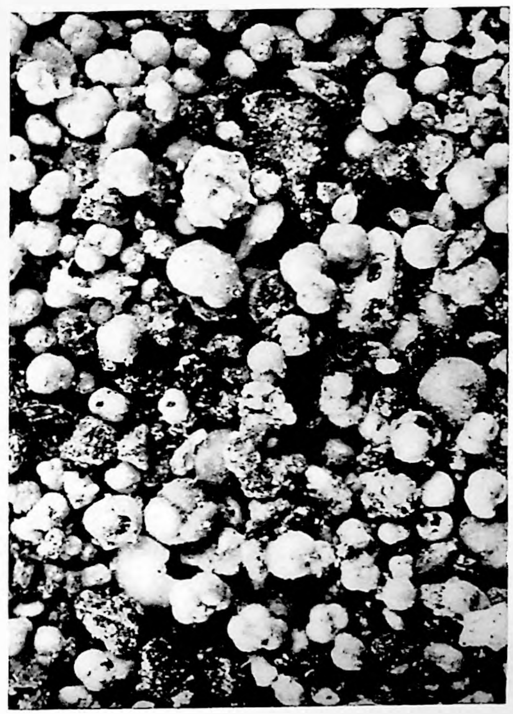


Photo 13. St. 299. Kawio Strait. — Globigerina Ooze with old-volcanic sand. (20 ×).

Photo 14. St. 148. N. of Soemba. — Globigerina Ooze, containing old-volcanic sand and clay. (10 ×). Sea floor parallel to lower side of photograph.

Photo 15. St. 34, upper part of sample. Makassar Strait. — Globigerina Ooze, containing sand and clay. (8 ×). Sea floor parallel to lower side of photograph.

Photo 16. S. 374, lower part of sample. E. of Kisar. — Globigerina Ooze, consisting principally of fine sand and clay. (10 ×). Photographed surface parallel to sea floor.

Photo 17. St. 65. Sulu sea. — Globigerina Ooze, consisting principally of fine sand and clay. (10 ×).
Sea floor parallel to lower side of photograph.

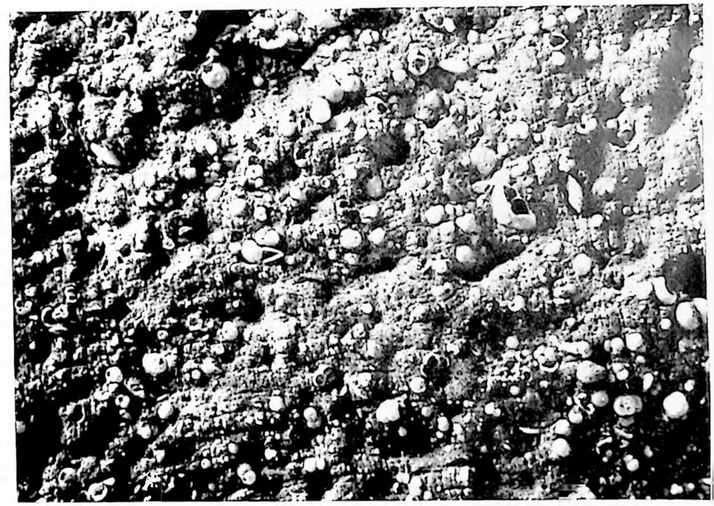


Photo 18. St. 93, lower part of sample. Ceram trough. — Globigerina Ooze containing much clay and a little sand. (12 ×).
Sea floor parallel to lower side of photograph.

Photo 19. St. 382, upper part of sample. Indian Ocean. — Globigerina Ooze consisting of partly broken foraminifera, much clay and a little sand; the sample as a whole shows several indistinct layers. (10 ×).
Sea floor parallel to lower side of photograph.

Photo 20. St. 189. Gulf of Bone. — Globigerina Ooze consisting of partly broken foraminifera, much clay and a little sand. (10 ×).
Sea floor parallel to lower side of photograph.

Photo 21. St. 118, lower part of sample. Timor trough. — Globigerina Ooze consisting of partly broken foraminifera, much clay and a little sand. (20 ×).
Sea floor parallel to lower side of photograph.

Photo 22. St. 51. N. of Celebes. — Coarse coral sand with Corals, Bryozoa, Gastropoda, Lamellibranchia etc. (3,5 ×).

Photo 23. St. 351. E. of Halmaheira. — Coarse coral sand with Corals, Bryozoa, Gastropoda, Lamellibranchia, Pteropoda etc.

Photo 24. St. 182L. Flores sea. — Coarse coral sand with Corals, Bryozoa, Gastropoda, Lamellibranchia, benthonic foraminifera etc. (5 ×).

Photo 25. St. 73, upper part of sample. Celebes sea. — Globigerina Ooze + Coral Mud. (10 ×).
Sea floor parallel to lower side of photograph.

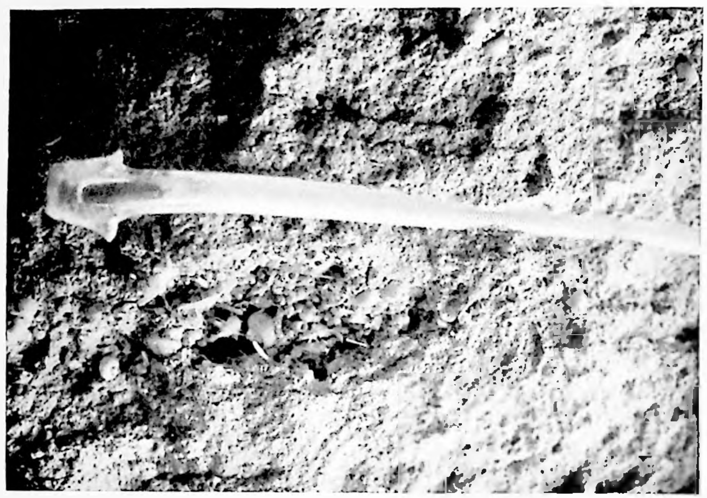


Photo 26. St. 129, lower part of sample. Timor trough. — Coral Mud consisting principally of fine sand and mud. (10 ×).
Sea floor parallel to lower side of photograph.

Photo 27. St. 119, fraction 0,5—1 mm. S. of Timor. — Foraminifera containing pyrite. (20 ×).
x = Foraminifera filled with globular pyrite aggregates.
$^{1}/_{2}$ = Foraminifera partly filled with pyrite.
p = Globular pyrite aggregate still showing the inner casting of a foraminifer.

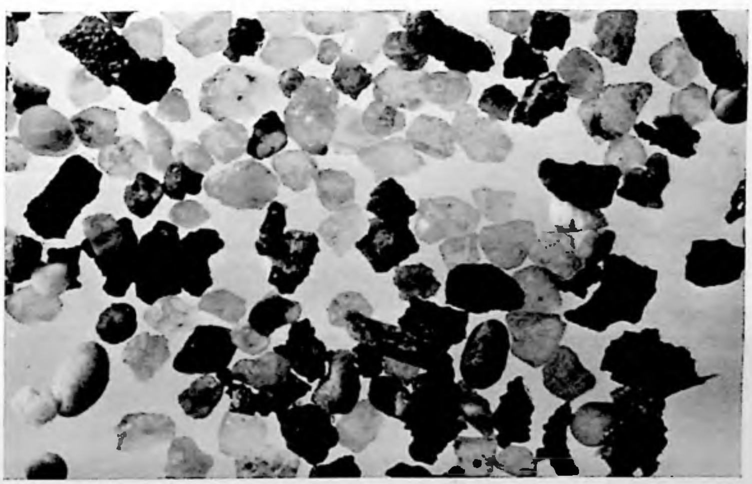


Photo 28. St. 305, fraction 0,2—0,5 mm. Celebes sea. — Globular pyrite aggregates with quartz, plagioclase and foraminifera. (20 ×).

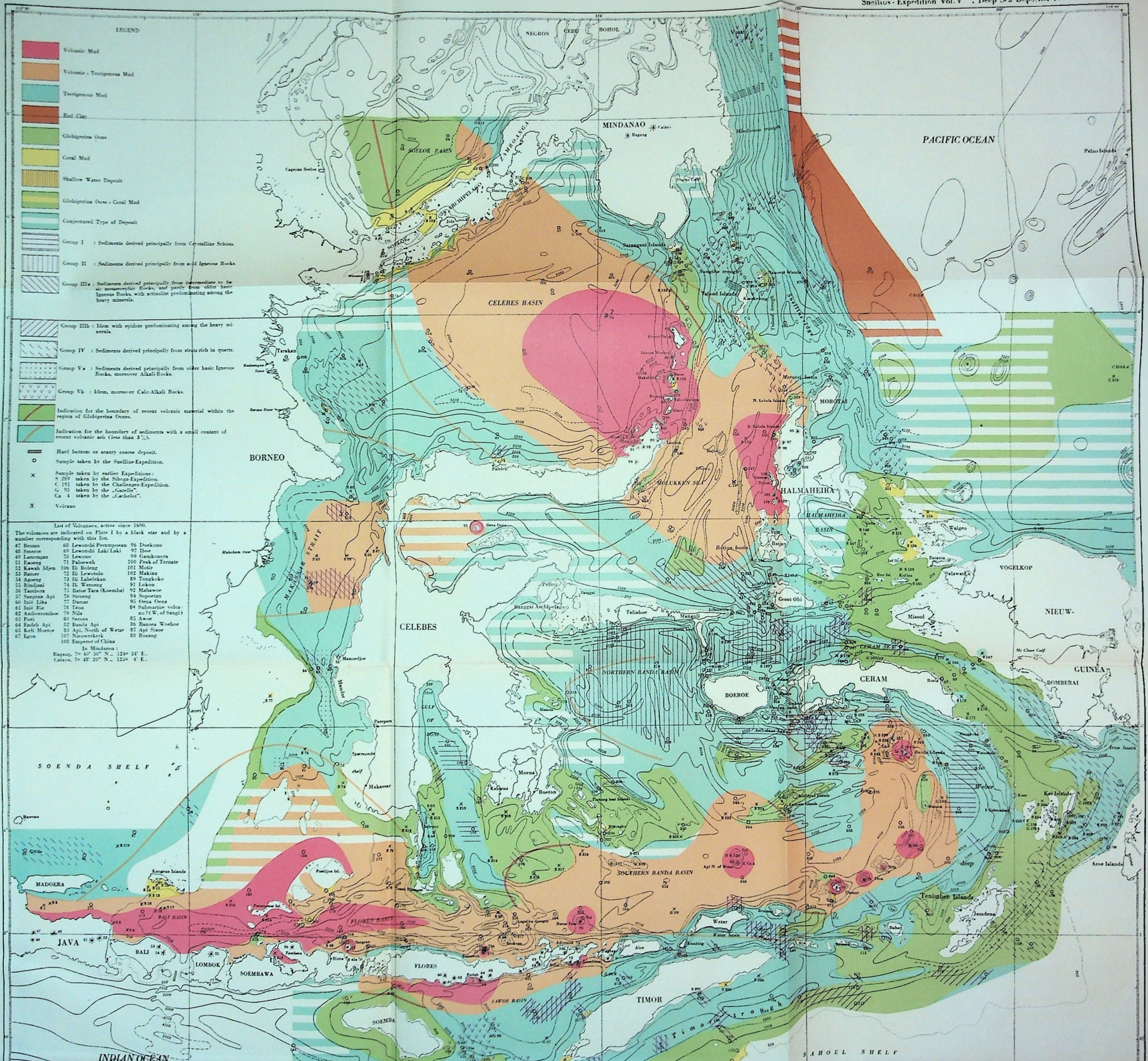
KAART DER BODEMMONSTERS VAN HET OOSTELIJKE GEDEELTE
VAN DEN OOST-INDISCHEN ARCHIPEL
DOOR GERDA A. NEEB.

Plaat I

CHART OF THE DEEP SEA DEPOSITS OF THE EASTERN PART
OF THE EAST INDIAN ARCHIPELAGO
BY GERDA A. NEEB.

Plate I

Snellius-Expedition Vol. V, Deep Sea Deposits, Part 3, Section II



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DE VERSPREIDING VAN DE TAMBORA-ASCH

DOOR GERDA A. NEEB.

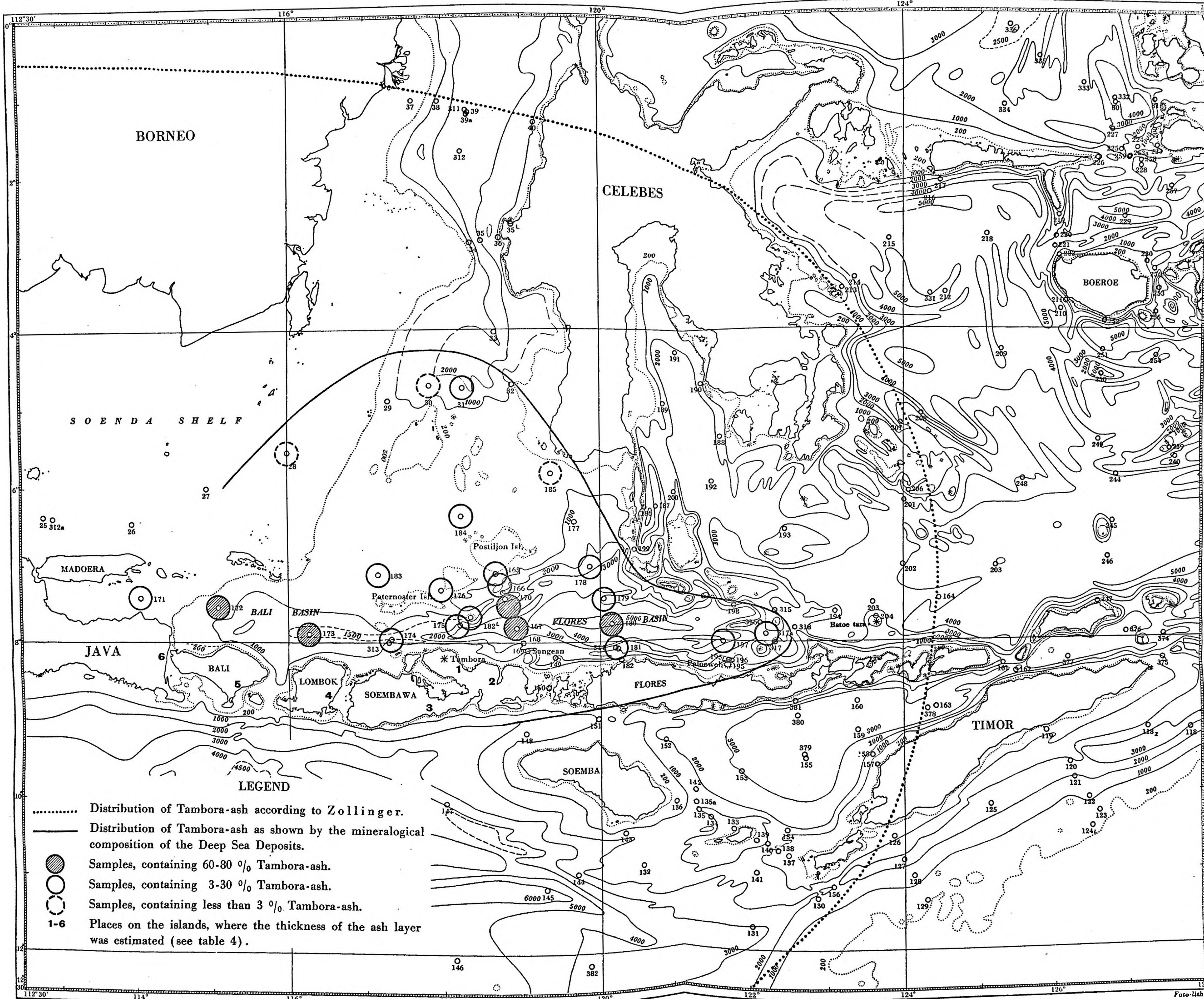
Plaat II

DISTRIBUTION OF TAMBORA-ASH

BY GERDA A. NEEB.

Plate II

Snellius-Expedition Vol. V, Deep Sea Deposits, Part 3, Section II



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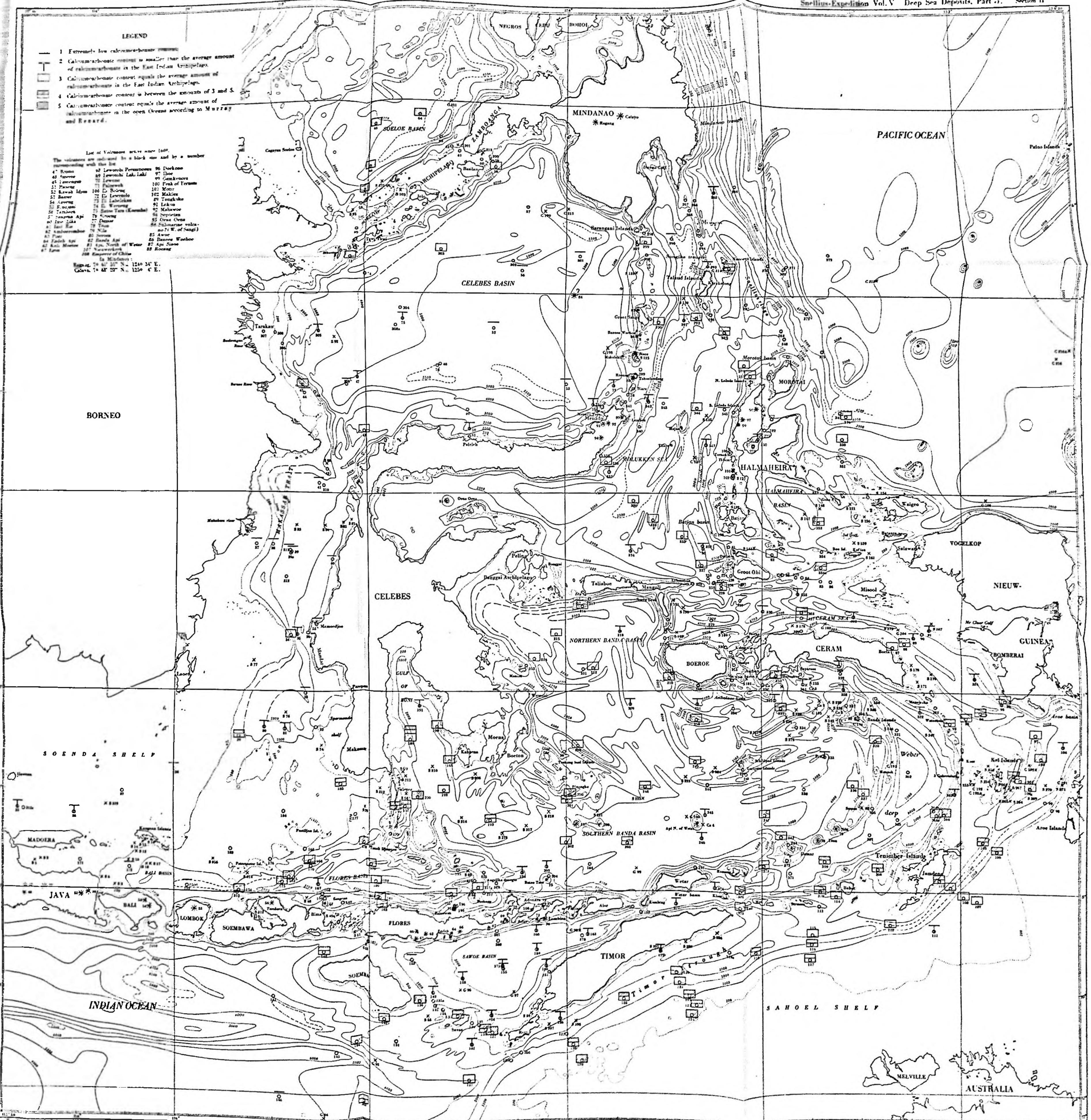
KAART VAN DE RELATIEVE KALKGEHALTEN DER BODEMSEDIMENTEN VAN HET OOSTELIJKE GEDEELTE VAN DEN OOST-INDISCHEN ARCHIPEL

Plaat III DOOR GERDA. A. NEEB.

CHART OF THE RELATIVE LIME CONTENTS OF THE DEEP SEA DEPOSITS OF THE EASTERN PART OF THE EAST INDIAN ARCHIPELAGO

BY GERDA. A. NEEB. Plate III



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